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EVOLUTION IN TRANSPORTATION ECONOMICS.*

BY

CLYDE B. AITCHISON, Ph.D., LL.D.,

Interstate Commerce Commissioner.

There could be no place more fitting for earnest discussion of a situation gravely affecting our people than this hall, dedicated to the memory of Benjamin Franklin, where cluster memories of Robert Morris, Alexander Hamilton, Stephen Girard, Friedrich List, Matthew Carey, and Henry C. Carey.

That the existence of a railroad problem—or, more accurately, a transport problem—gravely affects our economic and social stability and welfare has been developed in the discussions of the day, and it would not be profitable to cover again the same ground. The occasion should not degenerate into mere debate: the time and place call for counsel, not controversy. We may profitably recur to some fundamentals which may be lost to view when attention is concentrated on details.

From the inception of the railways, in this and in every other major nation, there have been strains within the industry, and external difficulties in adjusting and preserving proper relations between the railways and the public. At all times we have had to face some sort of a railway problem.

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The present phase of our own series of railroad problems has an intimate connection with world-wide economic, social, and political conditions, largely extraneous to the industry itself. As the spokesman for the American railways well says: "It is a business problem of the sort which applies, in greater or less degree, to every sort of business, and particularly to every form of transportation."[1] In truth, it is but one aspect of a long continued steadily growing world-wide, all-pervasive condition of industrial and political distrust, uncertainty, ill-feeling, instability, and insecurity, which must be resolved before industry can move forward.

Would that we could call to counsel the spirits of those great social scientists whose activities centered around this very place, and whose works are written broad in the history of the development of the American people: Franklin, the applied economist, apostle of thrift; Hamilton, master of political science, and planner of an industrial nation; Morris, America's first long-distance shipper; Girard, financial expert, who envisioned a correlated transport system necessary for the political preservation and material growth of the nation; Friedrich List, theoretical economist, keenly aware of the intimate relation between transportation and the material and spiritual life of a people; and the two Careys, Matthew and Henry, who boldly challenged economic doctrines unsuited to our national conditions; and Oliver Evans, perhaps not a social scientist, but a mechanical genius, prophet of the modern railway streamliner and the highway vehicle. Each of them would make a different contribution, but they would follow the same lines as in the days of their strength when with little precedent to guide they led the way through difficulties more menacing and disheartening than now confront us. They would recognize the far-reaching implications of the problem, and all their varied experiences and wisdom would be put to use in analyzing the material and social causes of the situation, and in devising, testing, and rechecking remedies suggested. They instinctively knew and applied a principle which has but comparatively recently received general acceptance, that neither private business nor govern-

[1] John J. Pelley, "Problems of the Railroad," *Annals, American Academy of Political and Social Sciences*, January, 1939, p. 124.

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ment can soundly deal with any great problem affecting a whole people on narrow lines, or otherwise than by considering all its social aspects.

Many consider the transportation problem as merely one of economics. That line of approach is convenient and useful for general purposes, although sooner or later the broader social consequences of the problem will demand attention. We quickly run into confusion by use of the term "economics" without differentiating between the great branches of the discipline which must be recognized as existing de facto, despite the claims of modern economists that coördination of theory and practice has been accomplished. Pure economics, or theory, applies within a more or less limited field; social economics relates to the problems of the growth and well-being of society; and national economics starts with the view-point of the statesman primarily concerned with the development and well-being of his State. To these may be added a disparate popular concept of the term "economics": the science or art of careful and provident management of affairs guided by practical wisdom. Here we have the original meaning of the term: prudent housekeeping.

A course of action which considered alone might seem prudent and provident may be unsound when tested by resort to pure theory, or may even be counter to the well-being of society, or distinctly individualistic or selfish, when viewed in another aspect. But each of these branch disciplines is indiscriminately termed "economics." One skilled in any of them may call himself an economist, and venture an expert opinion as an economist which carries all the weight attributable to one who speaks with authority as to the whole of economic science and art, but his opinion is positively misleading because based on an incomplete sense of awareness of other meanings of the term than those as to which the so-called expert is in fact skilled. The same confusion which seems unavoidable in the use of many of the terms of economic theory, such as "value," attends the term "economics" itself. So, in attempting to apply economic methodology to any problem, what may to one person seem to be governing principles may be considered by others as of little importance —it is a matter of training, view-point, and interest.

There are two procedural processes necessary for the practical application of economic theory. The first is the discovery and analysis of all needed relevant facts, and the second is the common sense interpretation of the facts with relation to their known effects on the production and distribution of wealth. The aim of applied economics is to determine or to adjust the course of future production or distribution of material goods to the requirements of a particular society. But such an application of power lacks direction unless we also know what wealth ought to be produced, and how it should be distributed in order to meet those requirements—and this no economist can finally answer without recourse to the other social sciences for required conditioning factors.[2] No one of the social sciences can yet give all the advice needed for us to recognize—far less to attain—that which is at once technically feasible, economically sound, legally possible, politically consistent, socially desirable, ethically laudable, and psychologically acceptable.

Economic doctrine has developed by subdivision into different areas. One recognized field of wide scope has come to be called the economics of transportation. As new and additional methods of transportation develop, the field expands. What we have been calling "economics of transportation" is now dividing into smaller areas, such as the economics of railway, highway, air, water, or pipe-line transportation, and these in turn into subgroups or subfields.

We must start with the premise that by definition economic generalizations applicable universally will apply to the production and utilization of transportation services. In consequence we must recognize as natural an initial tendency to the diffusion or distribution of an aggregated collection of property, and to subsequent reaggregation in larger units; and the tendency to coalesce into stronger systems, and to change a condition of competitive instability into one of noncompetitive stabilization. Other economic principles,

[2] Here, again, the modern economist would contend that anything which is salutary and beneficial in an economic way will in the long run prove to be socially desirable also. Like claims might be advanced for each of the other social sciences. For practical purposes we must still continue to deal with the social sciences as related, and overlapping, but not as a unitary discipline.

which although not considered as universal still meet with acceptance as normally sound, may prove to be as applicable to transportation as to any other business. However, obvious special characteristics set transport systems apart from the general mass of more simple, compact, and interchangeable property.

Upon the availability and efficiency of the transportation machine depends actually and relatively the whole national scheme of distribution of goods, including production and consumption. Transportation facilities and costs often determine where or in what form wealth shall be produced or shall be utilized. A break-down of transportation, or the imposition of charges which are prohibitive, may prevent the creation of wealth. After goods have been produced, poor transportation service or too high rates may result in wastage or degradation of value because the producer cannot move the goods to places where there is an effective demand.

There is an intimate causal relation between production and distribution and the social welfare of individuals, groups, localities, districts, and even nations. When the conditions for production and distribution are sound and fair, we expect national prosperity and good social conditions. Transportation practices and policies which in one sense of the word may be economically justified may tend to produce harmful social results, or be detrimental to the national good. On the other hand, a transportation policy or practice which may be socially or politically most desirable, may not conform to sound economic principles. The process of reconciliation is most difficult. The long, bitter contest over the long-and-short-haul principle in railway charges represents a head-on collision: the railways believe that freedom to depart from the long-and-short-haul rule is justified as a proper application of the familiar economic principle of spreading joint costs; to the intermountain country it is deemed a social need of high order that there be close conformity with the long-and-short-haul rule, both to afford all persons and localities an equality of opportunity, and to prevent the harmful effects of undue concentration of population and industry.[3]

[3] Illustrated by the speech of Representative Colden, Mar. 24, 1936, 80 Cong. Rec., p. 4444.

Transportation economics is still an indefinite science, although it began to evolve a systematic body of doctrine when one primitive man undertook to carry the belongings or person of the other across a stream or along a trail, and the two haggled over the barter. Their transaction matched the marginal utility to the carrier (*alias* cost of service), against the utility to the patron, or the value of the service. The same variety of general economic considerations may well have been in those untutored minds as experts apply today when they devise a freight rate structure. When transportation became more important and complex, what would be more natural than for disputants to call in the tribal authorities, or for the authorities to intervene on their own motion in the interest of peace and to prevent the creation of an undesired precedent? Historically, when new agencies of transport have come in, it is not long until "transportation problems" arise which require the interposition of the authorities to shape policies and to delimit the rights and duties of the parties to the transaction, and their relations with their respective competitors. In this evolutionary process, practice became usage; usage became custom; custom became law; laws necessitated institutions and administration; generally self interest has beclouded the controlling facts and swayed their interpretation and affected the principles sought to be derived therefrom.

At all times the stage of development of economic doctrine, whether expressed in doctrines alone or in laws, is a mirror image of prevailing social conditions—always allowing for some amount of time-lag. We may therefore find foreshadowed in old institutions or laws some vital principle of today in respect of matters as to which the controlling conditions have remained constant; on the other hand, accepted doctrine must be rejected when the basic conditions change. A body of transportation economic doctrines evolved to fit in an industrial competitive society, such as a modern democracy, would not prove useful in a totalitarian state where all industry was state-directed. Yet universally there may be certain principles which have long persisted and are still valid, or if discarded in the past, may reappear.[4]

[4] Compare Alexander Gray, "The Development of Economic Doctrine," p. 13.

Economic theory always has evolved slowly, even in its broad aspects. The body of special economic principles applicable to transportation evolved even later than general economic doctrine, and it took form only as complexity and importance compelled an increasing degree of specialization. One striking fact challenges attention: in the earliest legislation dealing with common callings, there was a recognition of ethical values and of social effects wrapped up in the words "just" and "reasonable," which in time became a cliché with a much narrower meaning: now these words seem to be once again assuming their former broad construction. To trace the evolution of the doctrines of transportation economics would be like looking through a kaleidoscope; every now and then we would be startled by the recurrence of some half-forgotten but striking design.

Any thoughtful consideration of transportation economics must deal with the transportation machine both as a form of wealth, and as constituting a means which conditions the general production and distribution of wealth.

The intricacy of the transportation business has forced us to make many different special studies of economic principles, but they are all related. We speak of the economics of location and construction; of operation; of financial affairs; of statistics and accounts; of control of intracorporate and intercarrier affairs; of rates or charges;—and the list ever grows. Each of these bodies of economic principles undergoes continual revision as technological progress makes obsolete what has been accepted as good practice, and as changes of governing commercial, industrial, political, or social factors develop new conditions. This process often advances more swiftly than theories can be devised to fit and be accorded general acceptance. One of the serious practical difficulties now is that the present plant and business is expected to carry the capital costs of much which the ruthless progress of the arts or change in governing factors has rendered obsolete and incapable of earning its own way.

Of transcendent importance to the government is its ability by regulation of the instrumentalities of transport, directly and effectively to accomplish a desired form of social control of persons and of their goods. This power often

remains dormant, but it is always available, and is particularly useful in a government such as this, where the powers of the central government are limited.

The public policy element strongly enters the field of transportation economics at this point. Each of the daily transactions of our transport agencies has in it an element of the public interest, to the end that the aggregate of all the transactions shall be so ordered and performed as to preserve such rights of the individual parties and of all others as are then regarded as socially important, and that each transaction shall make its contribution to the general public good, as the public good is currently understood. The right of the State to insert "political" before the word "economy" is so important that neither the transporter nor the private citizen patron is privileged to take any action counter to the expressed or future policy of the State. "Managerial discretion" of the owners of the transport agency can never long be successfully asserted counter to what the State determines to be in the public welfare.

But what the public interest may be is by no means a clearly defined or immutable matter: notions of what constitutes the public good often change violently and suddenly. When we alter our social aims and ends, new economic and political methodology must be made to fit, or there is an impasse. By the compulsion of a changed law or an altered public sentiment as to our social desiderata, entirely new economic conditions develop. These in turn become reagents which evolve still further altered economic situations. But it is often true in the field of transportation that changes in opinion as to what is desired are not dramatically voiced or clearly defined, and there is a time-lag in adapting old theories to new facts.[5]

Great emergencies or catastrophes, a financial or industrial debacle, a long continued period of sharply changing price levels, or technical improvements, have often so changed theretofore controlling economic factors as to produce startling reversals of opinion as to the objectives demanded by public interest. A few illustrations will develop the point. War-

[5] Winthrop M. Daniels, "The Price of Transportation Service," p. 12, quoting Dr. Max O. Lorenz.

time demands on transportation agencies are of a different, even contradictory character, from what is expected in times of peace. During a catastrophic drought preferences in transportation rates in favor of particular sufferers may be necessarily a part of a national plan for relief, and be so related to the conservation of the resources of the nation as to take precedence over the normal public policy of equal treatment for all persons.

When new forms of transport come into operation, their advent is at first viewed by the existing transportation agencies with complacency; and the body politic at first looks to the inexorable process of competition to see that in the long-run each form of transport is assigned to its proper place. It is not long until trouble begins, both between the rivals, and between the new agency and its patrons. When the newer agency becomes effective as an aggressive competitor, the State must determine whether it can permit continuance of a competitive course which threatens the destruction of both rivals, or if it must interpose in order to preserve them.

Men commonly endeavor to make effective their conclusions as to what is socially desirable, so that others can not prevent accomplishment of the desired results. They therefore try to write their economic theories into statutes or decisions, so as to correct or perhaps perpetuate some *status quo ante*, and thus as opinions change the law is evolved. These philosophies, crystallized into law, must, however, stand the test of experience. Failure may require further search for a remedy; partial success may suggest a possible extension or curtailment of the principle or amendment of the means of application. Legal institutions will work out differently in different sets of circumstances; as conditions change, that which worked successfully or unsuccessfully perhaps may later produce reversed results.

Continuously there goes on this never-ending process of trial and error, of discovery and correction, on the part of legislatures, courts and administrators as to those principles of economic action which find sanction in statute books and court reports. When a tonic becomes toxic, the prudent physician changes the medicine or the dosage. When index

numbers of the construction costs reverse their course, the public utilities, courts, commissions, and legislatures are likely to change their respective points of view as to the relative weight of reproduction and original cost as elements of value in determining the rate base. When competition so develops that it weakens all the components of our transport system, we must subject the competitive principle to scrutiny and ask it to justify itself as against any and all limitation.

Bearing in mind the fact that existing law is so often merely the embalmed currently accepted economic theory of past days, let us survey the shifts occurring within our own country.

The first American railways were compelled to protect the rates of their competitors, the canal carriers.[6] The "value of the service" theory was thus imposed upon the rails by law, not in deference to economic theory, but to insure preservation of existing transport agencies against the irresponsible competition of the unimportant, unstable, upstarts known as railways. But the railways soon demonstrated their superiority in service and cheapness, and began to make rail charges conformable to their lesser costs of service. The older forms of transport were thus forced to reduce their charges to meet those of the railways, if they desired to continue in business. The value of the service theory was in this manner made controlling as to the highway and canal carriers. Then followed a riotous period of railway development, the Civil War, the opening of the West, liberal public aid to rail construction, and alliances between the railways and the developing monopolies. The Granger movement, and state and federal regulation of the railways were successive stages in a popular effort to curb the fast growing monopolies, and many provisions of our present law are the outgrowth of particular phases of these conditions of the 70's and 80's.

Development of mass production methods in industry profoundly changed the whole economic situation. Ton-miles offered increased faster than carrying capacity of the railways.

[6] Balthasar H. Meyer, "History of Transportation in the United States before 1860," p. 355, 490.

Increased operating costs led to demands for additional revenues just at the turn of a period in which increasing utility had produced spectacular returns for many outstanding rail systems. This phase, lasting into the World War period, was one of bitter controversies, marked by insistent resort to the law for the adjustment of economic relations and by the enactment of retaliatory policies into laws. The exigencies of war could not tolerate such disturbances, and federal control and regimentation were inevitable. The Armistice brought demands for a "return to normalcy." It had become recognized that the relations between rail carriers and the public had never been perfectly explored, and that the existing regulatory code was one-sided and incomplete. Elaborate investigations by Congress in an atmosphere of statesmanship evolved a new economic charter for the railways. As to other forms of transport, need for a general overhauling of policies unfortunately was not then considered imperative.

The transportation act, 1920, which evolved,[7] was the first thoroughgoing attempt at translating economic planning into legal form. It formulated an integrated code, dealing with all important aspects of the problem presented by the carriers within its scope. In the haste of the legislative process some anomalies and even contradictions in theory crept in, which still stand in the law. Thus, it treats the railways as full competitors with each other, and seeks to preserve this status, while treating them as but parts of a national system, whose aggregation into larger units is encouraged. The underlying assumption was and is that the rail carriers will continue to be virtual monopolies. Congress declared a policy to keep two strongly competitive systems of transport, viz., the rail and water lines, *both* in full vigor. It could not foresee that its failure to balance regulation as between the two would stimulate such extensive and powerful highway competition as to destroy the possibility of vigor for either the rail or water lines.

Changes in economic conditions since 1920 have made obsolete many conclusions which seemed valid enough when reached. The Great Depression has forced a better under-

[7] Approved February 28, 1920, c. 91, 41 Stat. 474, et seq.

standing of the directness of the connection between railway stability and the general economic welfare. Hence we have given the roads liberal support in financing through the public treasury—on good collateral and at fair interest rates—and have attempted to design machinery for relieving the continuing burdens of excessive debt through facilitating reorganizations.

An experiment in coördination of transportation, combined with extensive provisions for research, under a Federal Coördinator of Transportation with a large and skilled staff,[8] failed to result in any considerable volume of economies; but the Coördinator obtained and made available a great amount of valuable factual information, previously inaccessible, and then needed in the appraisal of existing policies and the development of future plans. The major result was the Motor Carrier Act, 1935,[9] whereby Congress imposed upon the highway carriers a degree of regulation which then seemed appropriate. The administrative task imposed by that Act is stupendous, and progress is inevitably slow.

Congress had already twice declared its policy as to the relation between carriers and with their patrons: in the often cited section 500 of the transportation act, 1920, it had sought to preserve both rail and water carriers "in full vigor"; in the Hoch-Smith Resolution of 1925[10] it declared the true policy in rate-making to be such "that commodities might freely move." Ten years later, in the later Motor Carrier Act, it stated elaborately an additional policy as to motor carriers and their relation to the whole transport machinery of the nation. These three declarations of Congressional policy are difficult to reconcile, and it is questionable if separately or together they aid in arriving at a practicable, consistent working basis for the regulators or the regulated. No doubt the present Congress will consider as one of its major problems the bringing about of a greater degree of consistency and clarity in the expression of its own policy.

[8] Emergency Railroad Transportation Act, approved June 16, 1933, Title I, Emergency Powers, 48 Stat. 211, et seq.

[9] Approved August 9, 1935, c. 498, 48 Stat. 543, 49 U. S. C. Supp. sec. 301, et seq.

[10] Approved January 30, 1925, c. 120, 43 Stat. 801, 49 U. S. C. sec. 55 (1934).

All these economic changes indicate the need for thorough examination of applicable theories. Rate-makers and rate-users still plot supply and demand curves according to value of service and cost factors, and haggle for petty advantages, with a view-point no broader than that of primitive men bartering for ferriage across a stream in a hollowed out log.

Until the economic blizzard of the present decade, rate-making had high hopes eventually to attain recognition as a science. But rate-making along the previously accepted lines of science is possible only when the supply and demand for transport are both strong and steady, and when the supplier is in a position of apparent virtual monopoly. No form of transport now has such a monopoly as was assumed when Congress assigned the rate-making problem to its Commission. The joint-costs theory breaks down when there is no added traffic to be had, save by taking it away from some other essential transporter who is himself in desperate straits because of scanty business. The services of every transport agency are now freely reproducible in essence, if not in terms. Theories of distribution of fixed and joint costs among classes of traffic lose validity when they force the movement of high-grade, and formerly remunerative traffic from one agency to another, or compel a relocation of industry or change in industrial processes so as to make less transportation necessary.

The usual answer given is coördination. That term may mean much or little. As sometimes applied, it means merely the application of equally restrictive regulations upon each form of transport agency, or the relaxation of restrictive regulations down to the level of the most free type. Having thus seemingly been insured fair-play, the carriers are expected to battle out the issue under governmental supervision to insure a fair field and no favor. Extraordinary as it may seem, the suggestion is sometimes seriously made to take off all rules, and thus to legalize industrial mayhem. Either of these proposals means probable ruin to the survivor as well as to the vanquished.

No adequate national coördinated or coöperating system can result, if regulated or unregulated warfare is to be relied upon for demonstration of the adequacy of the forms of

transport to perform particular services. But if the other open course is taken, and if the government undertakes, through an agency of Congress, to apportion business among competing producers or competing carriers according to someone's conclusions as to what will be in the public interest, and what form of carriage should be encouraged, or what sections or industries shall be made more prosperous, it will be entering upon a course which it has heretofore definitely abjured. Such a power would have profound economic and social results, and should be vested in no body other than the Congress itself, unless Congress in making the delegation to an executive or administrative agency is completely aware of the vast effect of its action. Congress alone is competent to define the controlling national policy when embraced in it are a whole bundle of conflicting social conditions. It is not a task for an administrative agency. Rates of common carriers are now in theory formulated to conform to variations in transportation conditions: actually, the parties to every rate controversy seek a decision which will achieve certain economic and social results, although the rate-making authority, under the existing law, can consider the results only illicitly.

No patron of a carrier will continue to use unduly expensive or inefficient modes of transport, or pay more for a given service than it is worth, when several different agencies are in the market clamoring for his business. Nor need he pay or will he pay more than the sum for which he himself can perform the service. The familiar substitution principle of economic doctrine fixes the value of the service at the level of the cost of the cheapest available form of carriage. The private vehicle owner on the highway or the waterway believes he holds the whip-hand. To the extent that he is willing to act on that belief, he becomes the key to the traffic situation. By eventual reduction of the economic cost of transport by common carriers so that the price they must exact is below the amount for which the private vehicle owner can serve himself, the private operator will be eliminated as the controlling marginal user, and he will no longer set the maximum price for the carriage of his competitor's goods, as well as his own.

Needed stabilization of relations between the various transport agencies in respect of their individual charges and practices, can not come if they must be treated as distinct and unrelated entities. It is not possible, with our present store of knowledge and in the severe limitation of available time imposed by the crisis, to work out an ideal basis for adjustment which will reflect the inherent advantages and disadvantages of each form of transport. Immediate peace is better for each of them and for the traveling and shipping public than long-range freedom to continue warfare to their mutual destruction. Some degree of composition can be attained for the future, at least, if the services and charges of carriers may be related more directly one to the other, in the light of their relative importance to the nation and the harmonious development of efficient, cheap, and universal service. This may require readjustment of current economic theories and laws in which they find expression.

The effect of a composition of the strife between carriers of all types would be of great social benefit. In part it would be but a reversion to the initial situation when the rates of the railways, canals, and turnpikes were more or less closely tied together, and in some instances were protected by law. Doubtless such a composition as might be accomplished now would not reflect the adjustment of relations which should persist in the long run. Whatever is done will be subject to change as our knowledge of facts and appreciation of principles become more certain. But to assume that economic theory as applied to transportation will remain static when once expressed in a code of laws or an administrative order is to say that neither theory, laws, nor administration is adaptable to economic change, and all history denies that this is true.

If Franklin and his Philadelphia neighbors could join the discussion here, they would doubtless commend the earnestness of the effort being made in all quarters to ascertain what we should attempt to achieve and the methods by which these hopes may be made realizable. They would remind us that our situation is no worse—indeed, doubtless far more favorable—than in any other nation on earth, be it democracy or totalitarian state and whether under policies of government or private ownership or operation. Their counsel would be

for courage and facing the facts as they are. They would caution against undue reliance upon mere changes in forms of administration or of administrative methodology: they would deprecate the hasty application of novel theories without first subjecting them to careful, even relentless analysis of their natural and probable results in the light of history. They would stress sympathetic and unselfish consideration of the imponderable relations between transportation and the well-being of the whole people, and they would not shrink if it became necessary to devise some new legislative policies and guides for the executive and administrative agencies. They would doubtless counsel universal patience and calmness in the acceptance of whatever results are inevitable in this agonizing period of world-wide moral, social, and political upheaval.

Every nation must evolve its own social theories or accept them as the result of revolution. We choose to adhere to the competitive system, but how it may best be made to function in the common good is emphatically not a closed issue. Devising and applying a better policy is a task of real magnitude, and it calls for the coöperation of all the social sciences. Not the least important consideration is that projects in the field of transportation "cannot be crammed down the throats of those who must carry them out or conform to them. Legal compulsion can be used to advantage to bring recalcitrants and stragglers into line, but not to drive hostile majorities into action." [11]

That no nation yet has been able to make more headway than we simply means that none of them have retraced their steps so far as to reach the fundamentals.

Franklin would doubtless now bring the discussion to a close by observing that the matter before us compels us to a common concern, lest if we do not hang together, we all hang separately.

[11] Interstate Commerce Commission 52d Ann. Rep. (1938), p. 23.

FREE SPACE PROPAGATION MEASUREMENTS AT 75 MEGACYCLES.*

BY

G. L. HALLER,

Associate Radio Engineer, Aircraft Radio Laboratory, Wright Field.

INTRODUCTION.

In a study of the radiation characteristics of aircraft antennas in which the principle of similitude [1] is being used with scale models, one of the major problems was devising a system of free space propagation measurements in order to eliminate the error caused by the proximity to ground. The ground errors appear in two forms. The first is the actual distortion of the field in both amplitude and phase and the other is the unequal attenuation of the horizontal and vertical electrical fields. As an aircraft antenna is rather complex and may be made up of both horizontal and vertical components, any unequal attenuation may give a false representation of the true radiation pattern. The original work was done at a frequency of 75 megacycles and at a height of approximately one-half wave-length (2 meters) and serious errors were noted. This paper details the preliminary study and some of results of a tower system which was built to make free space measurements with little error due to ground effects.

ERRORS DUE TO GROUND REFLECTION.

Assume that a generator consisting of a single turn loop and a field strength meter using a dipole are elevated above ground a distance h as shown in Fig. 1 and designated as T and R respectively. The plane of the loop is vertical to the ground and the vertical dipole is contained in this plane. The distance between T and R is "a" and is to be at least 1.14 wave-lengths in order to reduce error due to direct coupling to less than 1 per cent.[2]* The wave which is reflected from the ground can be represented as being emitted

* Published by permission of the Chief Signal Officer, U. S. War Department.

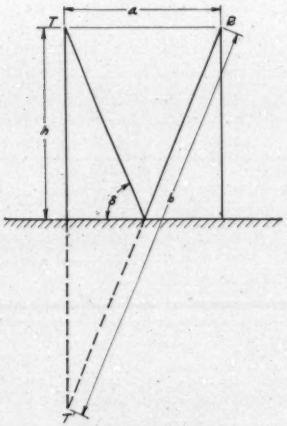
from T^1 which is at distance "b" from R.

$$b = \sqrt{4h^2 + a^2}. \tag{1}$$

Now the field at R due to the generator at T and its image T^1 is

$$E = \frac{120\pi^2 AI}{\lambda^2}\left[\frac{1}{a} + \frac{B}{b}\, e^{j\left\{\frac{2\pi(b-a)}{\lambda}+\theta\right\}}\right].^{*} \tag{2}$$

FIG. 1.



Direct and reflected waves.

where A = area of loop in square meters,
I = current in loop in amperes,
λ = wave-length of emitted wave in meters,
B = reflection coefficient of earth,
θ = reflection phase angle.

The $1/a$ represents the desired radiation term and the rest of the terms in the bracket represent the ground reflected wave. In the measurement of vertical polarization of the electric field the energy received by the dipole will be a component of the reflected wave due to the orientation of the dipole.

* See Appendix A.

In the case of horizontal polarization of the electric field the dipole will no longer be directive against the reflected wave but the transmitting loop is directive in the same manner as the dipole was in the vertical case. In either case the reflected wave is to be multiplied by cos δ then,

$$E = \frac{120\pi^2 AI}{\lambda^2}\left[\frac{1}{a} + \frac{B\cos\delta}{b}e^{j}\cdots\right], \tag{3}$$

but

$$\frac{B\cos\delta}{b} = \frac{B\cos^2\delta}{a}, \tag{4}$$

then

$$E = \frac{120\pi^2 AI}{\lambda^2 a}\left[1 + B\cos^2\delta e^{j\left\{\frac{2(b-a)}{\lambda}+\theta\right\}}\right], \tag{5}$$

where the second term in the bracket is the error due to ground reflection and is to be compared to a desired term of unity.

The reflection coefficient and phase change at the earth can be calculated for earth of known conductivity and dielectric constant from Fresnel's equations.[3] For a wave of vertical polarization of the electrical field

$$Be^{j\theta} = \frac{\epsilon'\sin\delta - \sqrt{\epsilon' - \cos^2\delta}}{\epsilon'\sin\delta + \sqrt{\epsilon' - \cos^2\delta}} \tag{6}$$

and for a wave of horizontal electrical field polarization

$$Be^{j\theta} = \frac{\sqrt{\epsilon' - \cos^2\delta} - \sin\delta}{\sqrt{\epsilon' - \cos^2\delta} + \sin\delta}, \tag{7}$$

where

$$\epsilon' = \epsilon - j2\sigma\lambda c, \tag{8}$$

ϵ = dielectric constant of earth in E.S.U.,
σ = conductivity of earth in E.M.U.,
δ = angle of incident wave with the plane of the earth,
c = velocity of propagation.

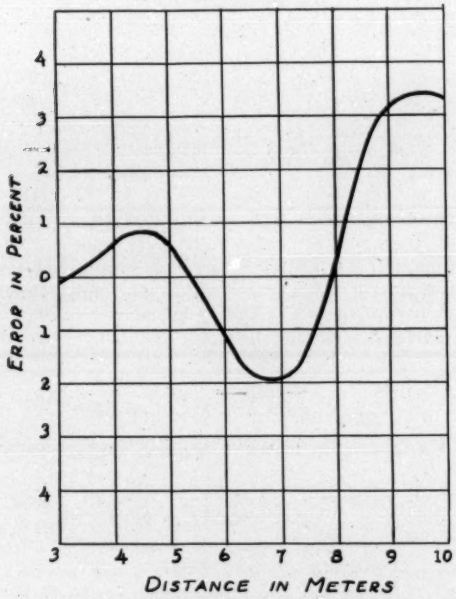
CALCULATION OF ERRORS.

From measurements[4] of ground constants values of B and θ were calculated for incident angles of from 0 to 90 degrees

and are shown in curves on Figs. 2 and 3. The permeability in these calculations was assumed to be unity.

A working height of 18 meters and distance of from 3 to 10 meters at a working wave-length of four meters was assumed. The error due to ground reflection was calculated

FIG. 2.

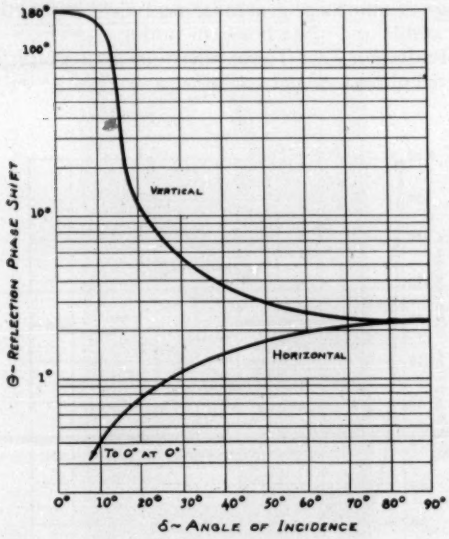


Reflection coefficient versus angle of incidence.

from equation (5). The values assumed for working heights and distances caused the incident angle to lie between 74 and 86 degrees at which region the B and θ (and consequently the calculated errors) for both horizontal and vertical polarization are very nearly equal respectively. Figure 4 shows the

error due to ground reflection in per cent. versus distance between generator and field strength meter.

FIG. 3.



Reflection phase shift versus angle of incidence.

MEASURING EQUIPMENT AND TOWER.

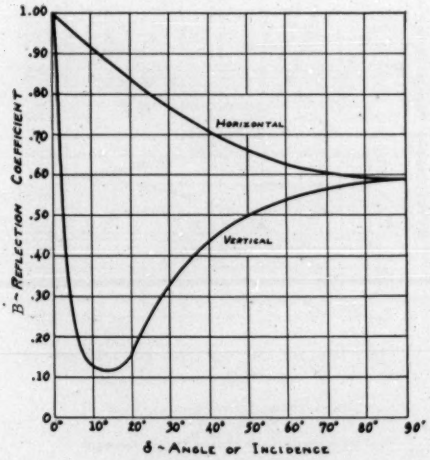
The generator shown in the photograph Fig. 5 with side shield cover removed, is a simple oscillator using an acorn tube Type 955 and is inductively coupled to the external loop. All battery supply is self-contained and is shielded as well as the oscillating circuit itself. The wiring diagram is shown in Fig. 6.

The field strength meter shown in the photograph Fig. 7 consists of a one stage radio frequency amplifier and a vacuum tube voltmeter using "acorn" tubes and a self-contained battery supply. The wiring diagram is shown in Fig. 8.

The dipole antenna, two meters in length, is connected to the input circuit through a transformer which is electrostatically shielded to reduce stray antenna effect. The field strength meter was calibrated in microvolts by means of a signal generator. Both loop generator and field strength meter are very stable and quite broad in tuning.

The Radiation Test Tower shown in photograph Fig. 9 is constructed almost entirely of wood and all large bolts are of

FIG. 4.



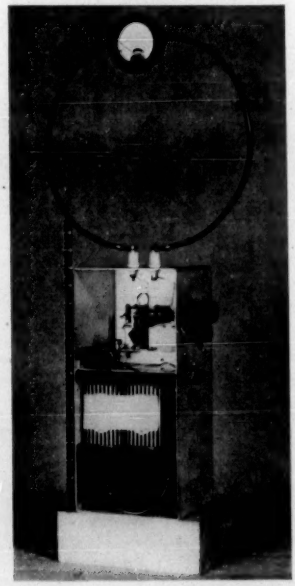
Calculated error due to reflection.

non-ferrous metal. The base of the upper runway is 50 feet from the ground and 70 feet long and 5 feet wide. A movable all wooden cart has been built as shown in photograph Fig. 10. This cart can be pulled by means of ropes and it also contains a central vertical axle which is used to mount the transmitter under study and which can be caused to rotate with ropes. The photograph shows a model airplane in position for a radiation pattern measurement.

PROPAGATION MEASUREMENTS.

As soon as the Radiation Test Tower was finished, tests of propagation were started to determine how nearly the radiation fields approximated the theoretical inverse distance curve for free space propagation. The generator was set up

FIG. 5.

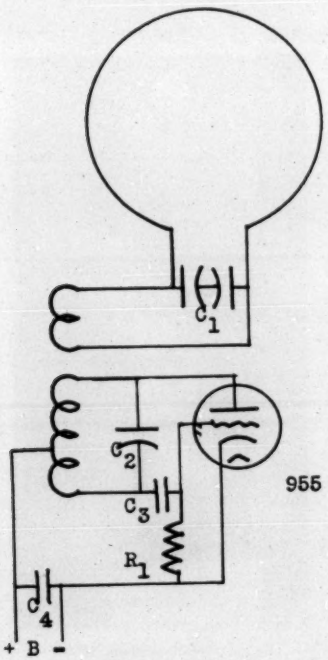


Test transmitter.

at one end of the runway and the field strength meter mounted on the movable cart. Both generator and field strength meter were mounted at a height of 18 meters above the ground. The field strength meter was then moved from a starting distance of 3 meters to a distance of 10 meters and incremental field strength measurements were noted. This

procedure was followed for both horizontal and vertical electric field patterns. The observers were at all times at the opposite end of the runway and in no case closer than 40 feet

FIG. 6.



C_1 100 uufd
C_2 25 uufd
C_3 100 uufd
C_4 100 uufd
R_1 5000 ohms

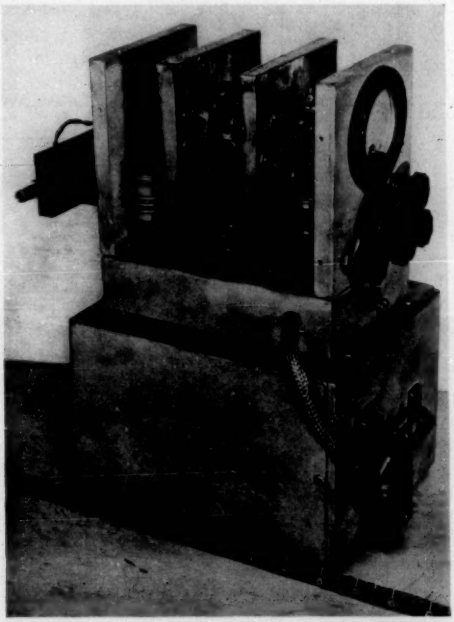
Wiring diagram of test transmitter.

to any of the apparatus. These tests were then repeated at a height of one meter from the ground and all results plotted as shown in Fig. 11.

CONCLUSIONS.

An examination of the propagation curves Fig. 11 indicates that the recorded values for both horizontal and vertical polarization taken on the tower follow very closely the

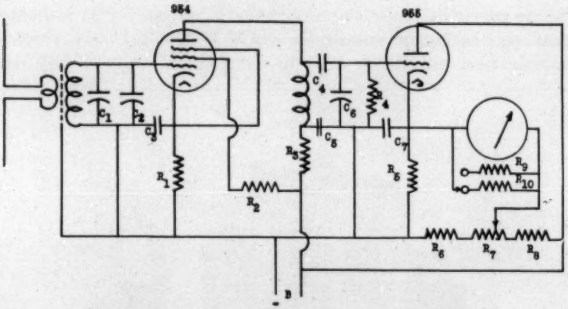
FIG. 7.



Field strength meter.

theoretical free space curve. The error is greater than that predicted by the calculation of ground reflection errors and can probably be charged to the tower structure itself, but is still well within limits of experimental error in this type of measurements.

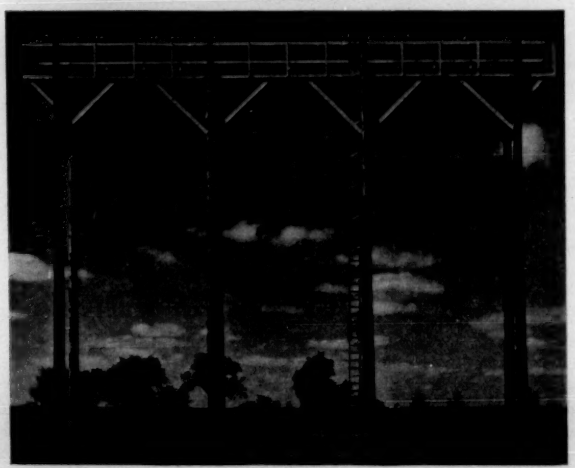
FIG. 8.



$C_{1,4}$	25 uufd	R_1	1,500 ohms	R_3	10,000 ohms
C_2	10 uufd	R_2	50,000 ohms	R_4	2,200 ohms
$C_{3,5,7}$	100 uufd	R_3	2,000 ohms	R_7	200 ohms
C_4	50 uufd	R_4	1 megohm	R_8	5,000 ohms
				R_9	10 meter shunts

Wiring diagram of field strength meter.

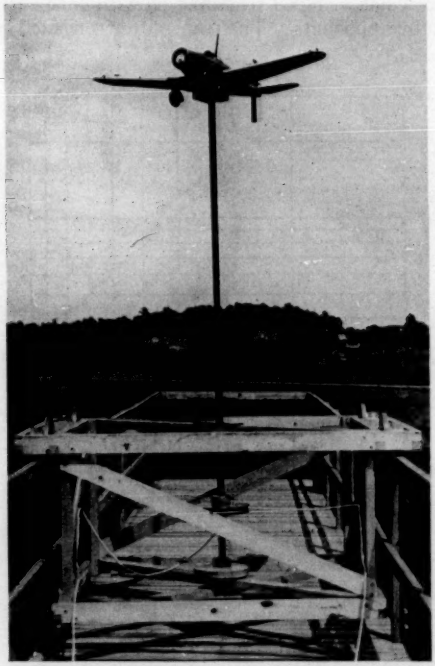
FIG. 9.



Radiation test tower.

It is interesting to note that the curve of horizontal polarization near the ground follows an inverse square curve which has been previously reported.[5] Also to be noted is

FIG. 10.



Airplane model mounted on tower.

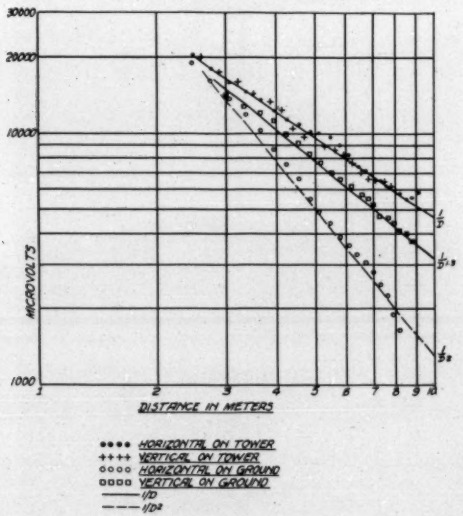
the differences of attenuation of the two waves on ground and their equal attenuation on the tower.

Earlier in this paper it was stated that for horizontal polarization the generator loop furnished a directivity against ground reflection which the dipole did not possess in the

horizontal position. In the measurement of a transmitter over which the pattern could not be controlled the field strength meter would use a loop antenna instead of a dipole for the horizontal measurements.

As a concluding test a transmitter configuration was measured which included transmission with both vertical and horizontal components. The transmitter consisted of a loop

FIG. 11.



Propagation curves.

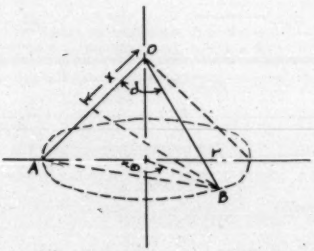
whose plane was at an angle of 45 degrees to the axis of rotation which was vertical. This loop can be represented by a dipole as shown in Fig. 12. The field strength meter dipole was also placed at an angle of 45 degrees to the vertical and at a distance of seven meters from the transmitter. The transmitter dipole was rotated as shown in the figure and the received wave was measured in relation to the angle of rotation. The coupling between the two dipoles varies from

maximum at zero degrees to a minimum at 180 degrees and the field strength curve should be a cardioid (see appendix B). Figure 13 shows the calculated pattern, the pattern measured on the tower at a height of 18 meters and the pattern measured

FIG. 12.

a. End View

b. Side View

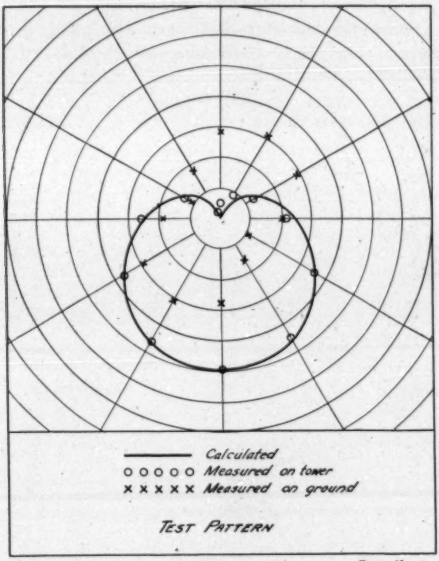


c. Development of Polar Pattern

Set up and development of test pattern.

at a height of 1 meter. As can be seen, the measurements made on the tower were near the calculated free space pattern and it is felt that the radiation test tower can be used for free space propagation measurements at 75 megacycles or higher frequencies with considerable confidence.

FIG. 13.



Test pattern curves.

V. 19

APPENDIX A.

Derivation of Field Strength for a Loop:

$$\epsilon^{\text{volts/meter}} = 300H^{\text{gilberts/meter}}, \tag{1}$$

$$H = 0.1\frac{\partial \Delta}{\partial r}. \tag{2}$$

Δ is the vector potential of the field at a distance r from the current flow.

$$\Delta = \frac{Il}{r}\sin\omega\left(t - \frac{r}{c}\right). \tag{3}$$

I is the current in amperes and l is the length of the

radiating element.

$$H = -0.1Il\left[\frac{\omega\cos\omega\left(t-\frac{r}{c}\right)}{rc}+\frac{\sin\omega\left(t-\frac{r}{c}\right)}{r^2}\right] \quad (4)$$

$$= -0.1Il\left[\frac{\omega}{rc}+j\frac{1}{r^2}\right], \quad (5)$$

now $\lambda = c/f$ and $\omega = 2\pi f$,

$$\epsilon = 30Il\left[\frac{2\pi}{r\lambda}+j\frac{2\pi\lambda}{2\pi\lambda r^2}\right], \quad (6)$$

$$= \frac{60\pi Il}{r\lambda}\left[1+j\frac{\lambda}{2\pi r}\right]. \quad (7)$$

Now the effective length l of a loop is $2\pi A/\lambda$ where A is the area of the loop in square meters.[6] Hence

$$\epsilon = \frac{120\pi^2 IA}{r\lambda^2}\left[1+j\frac{\lambda}{2\pi r}\right]. \quad (8)$$

If r is greater than 1.14λ then $[1+j(\lambda/2\pi r)] = 1.0$ with an error of less than one per cent.

$$\epsilon = \frac{120\pi^2 IA}{r\lambda^2} \quad (9)$$

for free space. To take account for the combination of the direct and reflected waves; the direct wave at a distance a,

$$\epsilon_a = \frac{120\pi^2 IA}{a\lambda^2} \quad (10)$$

and the reflected wave taking into account the coefficient of reflection β, the phase angle due to reflection θ, and the phase angle due the difference in path $[2\pi(b-a)]/\lambda$

$$\epsilon_b = \frac{120\pi^2 IA\beta}{\lambda^2 b}\, e^{j\left\{\frac{2\pi(b-a)}{\lambda}+\theta\right\}}, \quad (11)$$

combining

$$\epsilon = \frac{120\pi^2 IA}{\lambda^2}\left[\frac{1}{a}+\frac{\beta}{b}e^{\left\{\frac{2\pi(b-a)}{\lambda}+\theta\right\}}\right]. \quad (12)$$

APPENDIX B.

Derivation of Cardioid of Field Strength in Fig. 13.

In Fig. 12b R is the receiving dipole and T is the transmitting dipole. If T is rotated as shown the received field strength will be proportional to the projection of the moving element T on the stationary element R or in Fig. 12c, the length x in terms of the angle θ.

The chord

$$AB = 2r \sin \frac{\theta}{2}$$

$$= 2AO \sin \frac{\partial}{2},$$

$$AO = \sqrt{2}r,$$

then

$$2\sqrt{2}r \sin \frac{\delta}{2} = 2r \sin \frac{\theta}{2}$$

or

$$\sin \frac{\delta}{2} = \frac{\sqrt{2}}{2} \sin \frac{\theta}{2},$$

$$\sqrt{\frac{1 - \cos \delta}{2}} = \frac{\sqrt{2}}{2} \sqrt{\frac{1 - \cos \theta}{2}},$$

$$\cos \delta = \frac{1 + \cos \theta}{2},$$

but $$x = \cos \delta \text{ assuming } AO = \text{unity},$$

hence $$x = \frac{1 + \cos \theta}{2}.$$

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1. M. ABRAHAM, A Theorum on Models of Antennæ, *Jahrbuch d. draht. Tel. u. Tel.*, Bd. 16, page 67 et seq.
2. FRANZ EISNER, GUNTHER SUDECK, RUDI SCHOER AND OTTO ZINTOL, Increase of Effective Height of Trailing Wire Airplane Antennæ, DVL Report No. 207 (German).
3. FELDMAN, Optical Behavior of Ground, *Institute of Radio Engineers Proceedings*, Vol. XXI, No. 6, June 1933.
4. H. E. GIHRING, A Field Intensity Slide Rule, *Broadcast News*, Dec. 1935.
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6. W. BURSTYN, The Radiation and Directional Effect of a Few Antenna Forms in Free Space, *Jahrbuch d. draht. Tel. u. Tel.*, 1919, pages 362–378.

A TOPOCHEMICAL EFFECT IN POST-FIXATION DEVELOPMENT.*

BY

G. KORNFELD.

For an investigation on sensitivity centers, densities developed after fixation were desired. This method has the disadvantage of giving much smaller densities at the same exposures than the usual development, since, on the one hand, the latent image is partly dissolved in the fixing bath of thiosulfate, and on the other hand, sulfide fog is produced. Bullock,[1] therefore, used sodium sulfite for the fixing bath instead of sodium thiosulfate. Even so, the threshold speed was only 0.2 of the threshold speed produced by complete chemical development. Besides, the fixing process with sodium sulfite requires many hours or even several days. It seemed advisable, therefore, to return to thiosulfate as a fixing bath, using such modifications as had been suggested by previous investigators.

The dissolving power of thiosulfate for the latent image depends on the pH of the solution; this has been pointed out already by Lumière and Seyewetz,[2] and Eggert and Noddack [3] showed that even the developed image is dissolved in thiosulfate, but that this reaction can be greatly decreased by the addition of alkali. Meidinger [4] was able to increase the density of the developed image considerably by using for the preceding fixation a solution of thiosulfate which was either of very low concentration or was strongly alkaline. Recently, Kempf [5] found an optimum density with a solution containing 0.5 per cent. thiosulfate and 0.5 per cent. sodium hydroxide.

* Communication No. 749 from the Kodak Research Laboratories.

[1] E. R. Bullock, "Chemical Reactions of the Photographic Latent Image," p. 122. Eastman Kodak Co., 1927.

[2] A. and L. Lumière and A. Seyewetz, *Comp. Rend.*, **153**, 102 (1911).

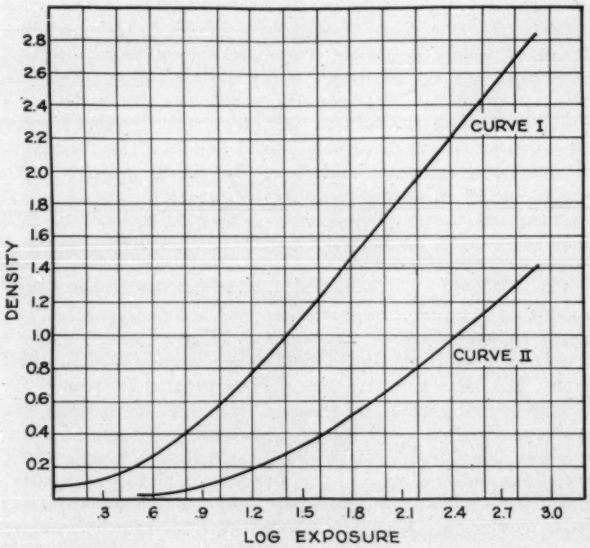
[3] J. Eggert and W. Noddack, *Z. Physik.*, **20**, 309 (1923).

[4] W. Meidinger, *Z. f. physik. Chem.*, **114**, 101 (1925).

[5] A. Kempf, *Z. f. wiss. Phot.*, **36**, 240 (1937).

At the same time, however, he found that even with a concentration of 1 per cent. thiosulfate the time of fixation was already increased to about one hour. It is further of great importance to avoid the presence of oxygen in the fixing bath; this was pointed out by Russell and Crabtree [6] in an extensiv-investigation on the influence of various agents on the reduce tion of the silver image. On the other hand, Dundon and Crabtree [7] showed that sulfide fog is produced by the presence of bacteria whose existence depends on the absence of oxygen.

FIG. 1.



In accordance with these findings, a freshly prepared solution of thiosulfate, with 0.5 per cent. sodium hydroxide added, was used as a fixing bath in the present investigation, with

[6] H. D. Russell and J. I. Crabtree, *J. Soc. Mot. Pict. Eng.*, **18**, 371 (1932).
[7] M. L. Dundon and J. I. Crabtree, *Am. Phot.*, **19**, 96 (1925).

precautionary measures against the presence of oxygen. The concentration of thiosulfate was 1 per cent., since the time of fixation was found to be too protracted with lower concentrations. Curve II in Fig. 1 gives the density curve of a strip of Commercial Film, which was suspended for one hour in the fixing bath, with the emulsion side facing downwards, and then developed for $3\frac{1}{2}$ minutes in an acid Elon developing solution. For a comparison, the density curve of Commercial Film obtained by chemical development (5 minutes in an Elon hydroquinone developer) is reproduced in Fig. 1 as Curve I. Gamma is lower with post-fixation development, which fact is favorable for the lower intensities of exposure. But even so, the percentage decrease in density is much larger for the lower densities than for the higher densities. This is especially unwelcome to an investigation of sensitivity centers, where the lower intensity exposures are much more significant than the high intensity exposures, which may produce ripening centers even without the presence of sensitivity centers. It seems very desirable, therefore, to find a method by which the density curve for post-fixation development can be extended to exposures of lower intensity. Such a method was actually found in consequence of an accidental observation.

Figure 2 gives the density curves of two film strips which received identical treatment with one exception: Each film strip was placed standing upright in its fixing bath, but on the upper end of one strip was the least exposed part (Curve III), and on the upper end of the other strip was the most exposed part (Curve IV). Both strips showed strong fog in their lower parts and incomplete fixation at their lowest ends.

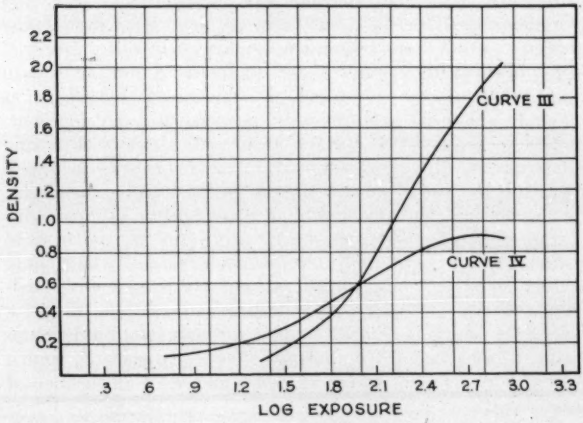
This phenomenon can be easily explained by considering the work on the kinetics of fixation, by Sheppard and Mees [8] and by Sheppard, Elliott, and Sweet.[9] They found that stirring had a decisive influence not only on the time of the fixing reaction, but also on its course. A film which was kept horizontally in the fixing bath, at some distance from

[8] S. E. Sheppard and C. E. K. Mees, "Investigations on the Theory of the Photographic Process," 126 ff. Longmans, Green and Co., London, 1907.

[9] S. E. Sheppard, F. A. Elliot, and S. S. Sweet, J. FRANK. INST., 196, 45 (1923).

the bottom, and with the emulsion side facing downwards, came nearest to the results obtained by stirring. This was explained by the fact that in this position of the film the

FIG. 2.



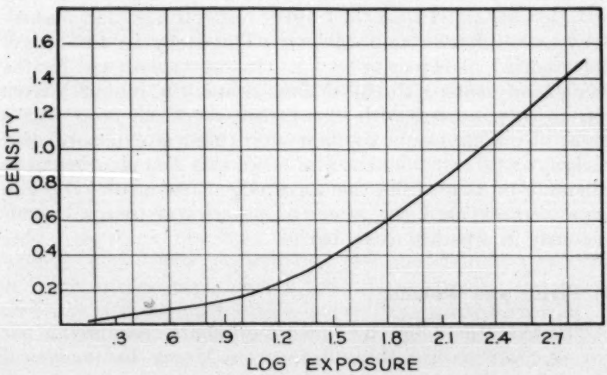
concentrated solution of heavy complex silver salts—which was formed by the attack of the fixing bath on the film—in floating downwards left free access for the diffusion of new fixing solution into the film.

In the case just reported, on the other hand, where the film strips stood erect in the fixing solution, the solution of the heavy salts, in floating downwards along the film strip, would prevent the access of new fixing solution to the film in the lower regions. This would slow down the fixing process in these regions as well as the dissolving of the latent image, whereas the production of fog by the decomposition of the complex salts would be favored by their higher concentration. Therefore, under given conditions of temperature, composition of the solution, and time, one should expect the density decrease to be an inverse function of the distance from the upper edge of the film, and this is the result expressed in the

curves of Fig. 2. One other condition had to be kept constant: the distance from the upper film edge to the level of the solution. When this level was raised, the velocity of the reactions increased, as was to be expected. The results were reproducible, under controlled conditions, to a surprising degree. Consequently, an attempt seemed hopeful to use this topochemical effect to increase the low density end of the curve. This implied a variation of all conditions in order to find the special circumstances under which, for very small densities, the increase of fog and the retarded dissolution of silver bromide could be outweighed by the retarded dissolution of the latent image.

	Strip	Strip
No. 73:	*a*	*b*
	1.35	1.39
	1.20	1.16
	0.96	0.93
	0.73	0.71
	0.52	0.51
	0.35	0.36
	0.19	0.20
	0.10	0.09
	0.06	0.06
	0.02	0.01

FIG. 3.



After numerous experiments, some results were achieved. The following table gives the densities of two strips of Commercial Film which had undergone fixation for one hour and twenty minutes between 71° and 70° F., standing in separate fixing tanks; in the subsequent development they were treated together. The intensities from step to step varied by the factor of two. Figure 3 gives the density curve of another experiment, which was carried out under slightly changed conditions (No. 79, level lowered for 2 cm., temperature between 73.5° and 71.5° F.). By comparing this curve with Fig. 1, the improvement in density for the low intensity exposures can be seen. For the highest exposure the density is about one-half of the density obtained with chemical development. And at an exposure which has only three times the intensity required for the threshold density with chemical development, this ratio is still not less than one-third.

EXPERIMENTAL DETAILS.

(a) Exposure:

All the exposures lasted thirty seconds and were made with a tungsten bulb (with the current kept constant at 10 amp.), screened by a thin opal glass plate, at a distance of 1 m. (Sensitometer X). Two different lengths of film strip were used, 30 cm. and 16 cm. in length, respectively, and accordingly two different step tablets. The steps in the longer tablet varied in intensity as $\sqrt{2}$. In the tablet used for the later experiments with the shorter strips, the intensity from step to step varied with the factor 2. Each step had a height of 0.8 cm.; only the first step (highest exposure) had a height of 1.6 cm. On the film strip, this first step began at a distance of 3 cm. from the upper edge. As a rule, two film strips were exposed one after the other, and treated simultaneously in separate fixing baths.

(b) Fixing and Washing:

The fixing bath for the final experiments contained 1 per cent. of cryst. sodium thiosulfate (from Merck, for analytical

use) and 0.5 per cent. of sodium hydroxide. For previous experiments the concentration of thiosulfate had varied between 1.1 and 0.8 per cent. The fixing solution was prepared only a few hours before use, to prevent the growth of bacteria; in preparing the solution—with boiled distilled water—and in filling the tanks, caution was exercised against the admission of oxygen. The tanks were prismatic glass boxes for the strips in the horizontal position, and glass cylinders for the vertical strips. The size of the boxes was $20 \times 11 \times 7$ cm.^{3} (the height was 7 cm.), and they had flat glass covers. At 4 cm. height inside the box stood a little table frame made from glass rods, to support the glass rod frame with the inserted film. Before and during fixation the tanks were almost completely immersed in a big water tank, to keep their temperature under control. The glass cylinders for the vertical strips had a radius of about 3.5 cm., were filled to a height of 32 cm. or more, and were covered with floating glass stoppers. The film strips were standing in frames of glass rods, of an approximate length of 31 cm., the shorter strips being inserted in the upper half of the frames.

The long alkaline treatment in the fixing bath had undesired consequences: the gelatin was softened to such an extent that stains and mottled stripes resulted in the subsequent development—sometimes preventing accurate density reading. This was actually the reason for using the shorter strips, since the time of fixing required for the lower parts of the long strips amounted to three hours and more. The density curves in Fig. 2 were obtained with the long strips. (So was the curve of chemical development in Fig. 1, but in this latter case, the length was insignificant.) Even with the short strips and shorter times of fixing a number of precautionary measures had to be taken to prevent stains and stripes. One of these was the exclusion of any other material but glass. Another one was the careful exclusion of dust, by wiping every surface with which the film strip was expected to come into contact. Since the back of the film was coated with a gelatin layer, the back had to be protected likewise.

Subsequent to fixing, the films were bathed for forty minutes in running water, which, however, was passed through

a silk filter in order to protect the films against any small particles which might be present in the water. To avoid any copper contamination, the metal parts of the tray syphon were chromium-plated. Finally, the film strips were thoroughly rinsed with cooled distilled water. Thanks to these measures and to the precautions taken with the development solution, the strips in the later experiments showed neither stains nor stripes.

(c) **Developing:**

The acid Elon developer was prepared according to the prescription given by Mees: 1 per cent. Elon, 1 per cent. citric acid, and 5 per cent. glacial acetic acid. Immediately before development, a 10 per cent. silver nitrate solution was added to the Elon solution (ratio 1 : 10). The Elon solution was completely colorless and remained so for hours if kept in a closed bottle at a temperature below 50° F. At higher temperatures, a faint pink color indicated the presence of oxidation products. This was found to be important for the developing process, since in the presence of these products the developing process was retarded in favor of a precipitation of silver crystals. Development at temperatures over 65° F. had the same effect. The procedure chosen, therefore, was to prepare the Elon solution not more than a few hours before use, to keep it in a dark bottle standing in ice water, and to develop between 55° and 57° F. After $3\frac{1}{2}$ minutes, development was completed; longer times slightly increased the higher densities, but left the lower densities unchanged.

The film strips were finally bathed in running water for twenty minutes, rinsed with cooled distilled water, rubbed with absorbent cotton, and dried in air. The densities, as well as fog, were determined with a Martens Densitometer. All the densities were corrected for fog. In the final experiments the fog density was between 0.2 and 0.3.

SUMMARY.

In alkaline fixing baths with a low concentration of thiosulfate, the course of the fixing reaction before development was found to be different at different heights of a film strip in the

vertical position. A probable explanation was proposed, and the phenomenon was used to extend, for post-fixation development, the density curve to lower exposures.

In an acid Elon bath the reduction of silver on the latent image competes with its reduction elsewhere more favorably at lower temperatures than at higher temperatures. The presence of oxidation products retards the first reaction in favor of the second.

A New Method of Controlling Temperatures—The Electronic Temperature Control.—F. F. FISCHER (*Heating and Ventilating*, Vol. 36, No. 11). The average electric temperature control consists primarily of a temperature sensitive element and a switch for making or breaking an electrical circuit. The temperature sensitive element may be simply a solid bar, a bimetallic strip, a bellows filled with gas or liquid, a thermocouple, or a resistance wire. The characteristics of the resistance wire type is comparatively unknown. The operation of resistance wire control systems, or electronic control systems, as they are frequently called is based upon the fact that an electrical conductor will change its electrical resistance in accordance with its temperature. In measuring the resistance changes, two wires are used, one placed outside the building and one on a typical radiator inside. The two wires are balanced and by the use of a modified Wheatstone bridge, electron vacuum tubes and a sensitive relay unbalance of the resistances is detected and a heat valve is operated. If desired, this electronic control circuit can be made so sensitive that it will operate on a 1/10° F. change in temperature and even the change of temperature from passing the hand across one of the resistance units will be enough to operate the control. When the control is applied to heating a building, it operates in accordance with outside as well as inside temperature. Thus when the outside temperature falls, the control system is thrown out of balance and the balance indicator operates the relay to send more heat to the radiators. As soon as the radiator temperature increases to the proper point the system is again balanced at the new outside temperature and the heat supply is shut off or decreased. The apparatus has only one moving part—the relay, it is easily installed, the wiring from the elements to the control box is low voltage wire, and it is comparatively low in cost.

R. H. O.

AN X-RAY DIFFRACTION STUDY OF GRAIN BOUNDARY INCLUSIONS IN STEEL.

BY

RAYMOND MORGAN, SYLVIA STECKLER AND E. B. SCHWARTZ,

Randal Morgan Laboratory of Physics, University of Pennsylvania, Philadelphia, Pennsylvania.

INTRODUCTION.

In a recent article [1] results were given of an electron diffraction study of the grain boundary residues obtained from the dissolution of electrodeposited iron and of transformer steel in ammonium persulphate solution. The transformer steel yielded residues too thick to be studied readily by electron diffraction. The grain boundary residues from electrodeposited iron gave diffraction patterns which could be accounted for by either iron carbide (Fe_3C) or goethite (α-FeOOH) or by both, since the patterns for these two materials are quite similar. It was pointed out that if α-FeOOH were present in the residue, it would not necessarily follow that it was in the grain boundaries since it might have been formed either by the oxidation and hydration of some grain boundary constituent or by a chemical reaction of the dissolved iron with ammonium persulphate.

The present paper is a continuation of the study of the nature of grain boundary materials. Inasmuch as it was not possible to renew the supply of electrodeposited iron, the work was continued by the use of transformer steel and a commercial steel of low carbon content. X-ray diffraction supplemented by spectrographic examination was used in analyzing the boundary residues. It was believed that a knowledge of the metallic elements present in the residues would simplify the laborious process of identifying the x-ray patterns. The spectrum analysis was especially valuable in this study because of the complex nature of the residues from the commercial steels.

Work quite similar in nature was done by Colbeck, Craven and Murray.[2] They studied the non-metallic inclusions in steel and iron by decomposing the metal with chlorine and

iodine, and making x-ray diffraction patterns of the filtered residues. When chlorine was used they found that the residue was predominantly amorphous. There was a general blackening of the photographic plate with a broad band, characteristic of amorphous material and a few sharp reflections showing the presence of some crystalline material which could not be identified. When iodine was used MnS was found to be in the residue. In both cases they concluded that the residues were largely amorphous.

PROCEDURE.

The chemical analyses of the materials studied are given in Table I.

TABLE I.

	Transformer steel.	Low carbon steel.
Total Carbon	.037%	.051%
Manganese	.061	.024
Phosphorus	.020	.008
Sulphur	.030	.024
Silicon	3.649	.004
Slag and Oxide	.070	.840
Copper	.072	.107
Total Aluminum	.095	
Metallic Aluminum	.073	
Total Titanium	.008	
Metallic Titanium	.003	
Nitrogen	.004	

Essentially the same process of dissolution was used as in the previous work. Strips of the steel were pounded on an anvil and annealed by heating in an oven to a bright red color and allowing to cool slowly. The surfaces were cleaned by filing and by polishing with fine emery cloth to remove all visible films.

Laminæ, about 10 × 5 × 0.1 mm., cut from the strips immediately after polishing, were degreased with carbon tetrachloride and placed in a 12 per cent. solution of ammonium persulphate for the dissolution of the metal grains. The grain boundary residues left after all the grains disappeared were found to be extremely strong as compared to the films formerly obtained from transformer steel, and particularly from electrodeposited iron. It was even found unnecessary to carry out the process at a low temperature as

was previously done; satisfactory results were obtained at room temperature. After dissolution of the iron, the grain boundary residues were washed by a slow stream of distilled water until no acid reaction was detected by litmus paper. The residues were collected and dried in a desiccator. To aid in the identification of the compounds in the residues, some of the material was heated to 650° C. in an electric oven to determine what transformations were produced. X-ray diffraction patterns were made of the different samples of the heated and the unheated materials using Cu-Kα radiation. Spectrum analyses were made of the unheated residues.

RESULTS AND DISCUSSION.

The grain boundary residues of the two types of steel differed markedly in appearance. Those from the transformer steel, while in the water, were thin, honey-combed films, very cohesive and free from opaque inclusions. Furthermore, they were strong enough to withstand considerable agitation and transference from one dish to another. The strength of the films and their homogeneity indicated that they consisted largely—if not solely—of grain boundary material and not of materials occluded in the grains.

Low Carbon Steel.

The spectrum analysis of the grain boundary residues from the dissolution of the low carbon steel showed the main constituent to be iron. Appreciable amounts of manganese and chromium were also present, as well as traces of copper, titanium, and silicon. The diffraction data obtained from the x-ray patterns of the heated and unheated residues are given in Table II. Also included in the table for comparison are the data for ferrosic oxide (Fe_3O_4),[3] and the normal ferric oxide (Fe_2O_3). An examination of the table shows that in the case of both the heated and unheated material, Fe_3O_4 was present, whereas Fe_2O_3 was present only in the heated residues. It was concluded, accordingly, that some of the Fe_3O_4 was oxidized to Fe_2O_3 when the residue was heated in air.*

* In a preliminary report of this work in the *Bulletin of the American Physical Society*, 13, No. 2, page 11, it was stated that the diffraction patterns indicated the presence of Fe_3C in the residue materials. Due to improper adjustment of the slit system of the x-ray camera there were initially obtained in the patterns several extraneous lines which led to this erroneous conclusion.

There are several reflections not accounted for by either oxide, which show the presence of a small amount of other

TABLE II.

X-Ray Diffraction Data for the Grain Boundary Residues of Low Carbon Steel.

Residues not heated. Average of 5 plates.			Fe_3O_4		Residues heated to 650° C. Average of 2 plates.			Fe_2O_3	
$\frac{d}{n}$.	*I.*	No. of plates on which line occurs.	$\frac{d}{n}$.	*I.*	$\frac{d}{n}$.	*I.*	No. of plates on which line occurs.	$\frac{d}{n}$.	*I.*
					3.72	vw	1	3.68	vw
					3.45	m	1		
2.97	w	5	2.97	w	2.97	m	2		
2.82	m	1			2.84	vw	1		
2.76	m	1							
					2.70	s	2	2.69	vs
2.65	vw	3							
2.52	vs	5	2.53	vs	2.53	s	2	2.51	s
2.41	vw	2	2.42	vw	2.41	vw	1		
					2.22	vw	2	2.20	vw
2.15	w	5							
2.08	w	5	2.10	w	2.10	w	2		
1.98	vw	3			1.95	vw	1		
1.90	vw	2							
					1.85	m	2	1.84	m
					1.77	vw	2		
1.71	vw	4	1.71	vw	1.70	m	2	1.69	m
					1.65	vw	1		
1.61	m	5	1.61	s	1.61	m	2	1.60	vw
1.57	vw	1							
1.515	vw	5							
1.48	m	5	1.483	s	1.49	m	2	1.485	m
					1.46	w	2	1.452	m
1.39	vw	1			1.38	vw	1	1.35	vw
1.37	vw	1							
					1.31	vw	1	1.308	vw
					1.28	vw	1		

Letters used in describing the intensities are:

vs—very strong
s—strong
m—medium
w—weak
vw—very weak.

crystalline material. These lines which, with three exceptions, were very weak and occurred on only a few of the plates, were insufficient for identification. There was a general

blackening of the photographic film that indicated the presence of amorphous material. The pronounced character of the x-ray patterns of the iron oxides shows that the x-ray analysis is in agreement with the spectrum analysis in indicating that iron compounds are the major constituents in the grain boundaries.

The identification of Fe_3O_4 in the residue of the low carbon steel raises the question whether or not the residue was contaminated with a surface film, since the surface film on iron is predominantly composed of ferrosic oxide.[4, 5] It is believed that the Fe_3O_4 was not due to a surface film, because it was not obtained in the case of the electrodeposited iron and transformer steel, which were treated in the same manner as the low carbon steel. Furthermore it is not believed that Fe_3O_4 was present in the grain boundaries of the steel but that it was found in the residue material as the result of the oxidation of FeO which was present originally in the grain boundaries.

Transformer Steel.

The spectrum analysis of the residue from the transformer steel showed that it consisted mainly by silicon and titanium, with a small amount of aluminum, and traces of iron, copper, and manganese present. The x-ray diffraction data for the heated and unheated residues are given in Table III. Also included in this table are the data for titanium carbide (TiC),[3, 6] rutile (TiO_2),[3] anatase (TiO_2),[3] and aluminum nitride (AlN).[7]

A comparison of the x-ray reflections shows that in the case of the unheated material, there is present TiC. In the case of the heated material there are present TiO_2 (rutile), and TiO_2 (anatase). It is evident that on heating the residues titanium carbide was oxidized to both rutile and anatase. It is seen that there is also good agreement with the spacings of AlN for both the heated and the unheated residues, but the fact that it is decomposed by water and acids in its ordinary form makes its presence in the residue material uncertain.

It has not been possible to identify positively any other compound from the spacings left after the identification of the titanium compounds. It is probable that the extra lines

are due to the incomplete patterns of traces of more than one compound. Also it appears that another transformation,

TABLE III.

X-Ray Diffraction Data for the Grain Boundary Residues of Transformer Steel.

Residue not heated. Average of 4 plates.			TiC.		AlN.		Residues heated to 650° C. Average of 4 plates.			TiO_2 rutile.		TiO_2 anatase.	
$\frac{d}{n}$.	*I.*	No. of plates on which line occurs.	$\frac{d}{n}$.	*I.*	$\frac{d}{n}$.	*I.*	$\frac{d}{n}$.	*I.*	No. of plates on which line occurs.	$\frac{d}{n}$.	*I.*	$\frac{d}{n}$.	*I.*
							4.03	m	1				
							3.52	m	3			3.52	vs
							3.45	s	1				
							3.25	s	4	3.24	s		
2.98...	vw	1											
							2.82	m	2				
2.71...	m	4			2.69	s	2.70	m	4				
2.60...	w	1											
2.48...	m	4	2.49	s	2.49	m	2.50	s	4	2.49	s		
2.38...	m	4			2.36	s	2.37	m	4			2.37	w
							2.29	vw	2	2.29	vw		
2.22...	vw	1					2.19	w	4	2.19	w		
2.14...	s	4	2.15	vs									
2.08...	vw	1					2.08	w	4	2.05	vw		
							2.00	m	2				
							1.89	vw	1			1.88	w
1.84...	vw	2			1.83	m	1.83	vw	3				
							1.78	vw	1				
1.73...	vw	1					1.74	w	4				
							1.69	s	4	1.69	vs	1.70	w
1.61...	w	4					1.62	w	3	1.62	w	1.66	w
							1.59	w	2				
1.56...	w	4			1.56	s	1.55	vw	3				
1.51...	m	4	1.52	m									
1.49...	vw	1					1.49	vw	4	1.48	vw	1.48	w
							1.45	w	3	1.449	vw		
							1.42	vw	2				
1.42...	w	3			1.418	s	1.40	w	3				
1.38...	w	4			1.35	vw	1.36	vw	4	1.355	w	1.36	vw
1.32...	vw	3			1.323	s	1.31	vw	4			1.33	vw
1.29...	w	4	1.30	w	1.29	m	1.27	vw	3			1.26	vw
1.24...	vw	3	1.24	vw			1.23	vw	3	1.245	vw		
1.23...	vw	2					1.22	vw	1				
1.19...	vw	1			1.188	w	1.19	vw	1				

The same letters are used in describing the intensities as in Table II.

besides the formation of TiO_2 compounds, took place in heating this residue to 650° C., because of the appearance of a few strong higher spacings in the patterns of the heated

residue. It has not been found possible to determine what the transformation was.

It is of interest to note that although silicon is by far the largest impurity in the transformer steel—making up 3.649 percent. of the composition of the steel—and was found by spectrum analysis to be a main constituent in the grain boundary residue, nevertheless we were unable to identify the x-ray pattern of a silicon compound in any of our exposures. Possibly the silicon occurs in amorphous form. There was a considerable amount of general blackening of the photographic film which would indicate the presence of amorphous material.

The case of titanium was very interesting. Both the spectrum analysis and the x-ray patterns showed that it constituted a large portion of the residue. There was present only 0.008 per cent. titanium in the steel, and there must have been, therefore, a rather marked segregation of the material to the grain boundaries as TiC. The occurrence of the TiC in the grain boundaries is quite different from what Comstock [8] observed in the case of 18–8 stainless steel, where the TiC instead of being segregated at the grain boundaries is scattered within the grains.

Effect of Cold Working and Heat Treatment of Metals.

In the course of this study a number of observations were made, which bore out the description given by Tammann [9] of the effect on the grain boundaries of cold working and heat treating metals. He showed that when metals are cold worked, as in rolling, the skin which surrounds each metal grain is torn by the elongation of the grain brought about by rolling. He showed, further, that if the metal is heated subsequently, that recrystallization takes place, and the newly formed grains are surrounded by skins or grain boundary membranes.

In the preparation of the transformer steel laminæ, the method used consisted of clamping the strips of steel to a rigid support and using a fine file to remove the heavy oxide coating. To speed up the process, a sanding machine was tried for cleaning the laminæ instead of a file. The specimens cleaned on the sander were subjected to considerable bending and whipping, and they gave boundary residues that were broken

and non-homogeneous. The filed specimens gave boundary residues that were unbroken and homogeneous and retained the outline of the original laminæ.

In the case of the low carbon steel, the specimens were cut from the edge of a plate one quarter of an inch thick. Upon dissolution in the ammonium persulphate, it was found that the boundary residues were very weak and brittle in the middle as compared with the outside portions, and the action of the ammonium persulphate on the middle of the specimens was much more rapid than on the outer portions. This difference is probably due to the fact that in rolling the steel, the outside portions received a higher degree of working.

The transformer steel used in this work was found to be markedly different from the transformer steel previously studied. The steel first used was obtained from a small audio transformer. The grain boundaries as described previously [1] were non-homogeneous until after the metal was pounded and carefully annealed. Even after this treatment, it was of advantage to carry out the process of dissolution at a low temperature to keep the film intact. The transformer steel used in the present study was taken from a large power transformer. It was found that homogeneous, cohesive films were nearly always obtained with this steel, whether or not the specimens were annealed in the laboratory. Also, the dissolution was accomplished satisfactorily at room temperature. Apparently this difference in the character of the grain boundaries was due to a difference in the fabrication of the steels, since the chemical composition was very nearly the same in both cases.

CONCLUSION.

In neither the transformer steel nor in the low carbon steel was α-FeOOH found in the grain boundary residues. It, therefore, is evident that in the case of the electrodeposited iron previously reported α-FeOOH was not present because of a chemical reaction between the dissolved iron and the ammonium persulphate solution.[1]

The x-ray data show that the impurities segregated at the grain boundaries of both the transformer and the low carbon

steel occur largely in the crystalline form and to a small extent in the amorphous form.

It is believed that this method of studying the grain boundary material in metal is a substantial aid in determining the segregation of impurities to the grain boundaries. Consequently it offers a means of determining the effects of the distribution of impurities on the properties of the metal.

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Cotton's Uses in Relation to Housing and Construction.—In an article in *Manufacturers Record*, Vol. 100, No. 12, Charles K. Everett of the Cotton-Textile Institute states that the utilization of cotton fabric for interior and exterior coverings, as well as in the actual construction of low cost homes, has now progressed to the point where specially prepared products are scheduled for commercial production early in 1940. While it is true that in "cotton houses" of varying type erected to date the fabric has been applied on the job, it is more than likely that the greatest use of fabric for facing outside walls will come in its application at the plant producing prefabricated units, such as wall sections of, say, 4′ × 8′ size. For that possibility plywood panels appear to be in a vantage position. Even though the plywood may be manufactured by the hot press resin-bonded process to produce wall board that is permanently impervious to water or moisture, the fact remains that the outside wood ply, if exposed to the elements, will check and develop cracks. It is therefore not surprising, though highly significant and encouraging to the cotton-textile industry, that Lawrence Ottinger, president of the U. S. Plywood Corporation, the largest in the field, has endorsed without reservation the soundness, as well as the economy, of using a fabric facing on plywood to eliminate checking and grain raise and to provide a finish preferable to that of the wood. It is expected that from further experiments now in process there will come in 1940 a commercial distribution of fabric faced fir plywood cut to size for not only exterior and interior wall paneling, but also for applying to both flat and pitched roofs. By providing overhanging lips of fabric, which can be tightly lapped over joints with an adhesive, the troublesome problem of how to make watertight joints between prefabricated panels is easily resolved.

R. H. O.

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A GENERAL EQUATION OF STATE: EQUATIONS FOR AMMONIA AND STEAM.*

BY

J. L. FINCK, Ph.D.,

The J. L. Finck Laboratories, New York, N. Y.

I. INTRODUCTION.

This is a continuation of a previous paper published in this JOURNAL.[1] Briefly, the proposition as presented in the earlier paper is as follows. The writer considers the possibility of enlarging the assemblage of thermodynamic states by including states of supersaturation and states outside the range of the mass-action law; i.e., those usually referred to as "meta-stable" states. Catalysis is also introduced as a factor in thermodynamic considerations. It has been indicated in this paper that the assumption that all states in this enlarged assemblage are in stable equilibrium is not inconsistent with the two basic laws of thermodynamics. Following this line of thought, it is shown that a thermodynamic system involving a transformation of a single type, whether it be entirely in a gaseous phase, or as a liquid-vapor, will have three instead of two independent variables. If the system is closed, and V is the volume and M the mass of the entire system, we may define the specific volume v by the equation $v = V/M$; then

$$\epsilon = F(p, T, v) = G(p, T, x)$$

or

$$v = \Phi(p, T, x), \tag{5}$$

where ϵ is the internal energy per unit mass, p the pressure and T the temperature.[2] For a single gaseous phase, where

* Presented at the meeting of the American Physical Society in New York, February 25, 1939.

[1] Vol. 225, No. 4, April 1938; pp. 411–435.

[2] All equations quoted from the previous paper bear the same numbers here. The numbers of the new equations appearing in this paper are a continuation of those of the first paper.

the transformation consists of molecular dissociation, x is the degree of dissociation. For a liquid-vapor system, where the transformation consists in changing from the liquid to the vapor phase, x is the fraction of the total mass in the vapor phase. For a liquid-vapor system, if E is the total internal energy and M the total mass, then $\epsilon = E/M$.

Another conclusion arrived at is that the Clapeyron-Clausius equation may be generalized so as to include dissociation within a single gaseous phase, and also to transformations in the enlarged assemblage of states. If $\lambda_{p,\,T}$ is the latent heat of transformation (dissociation, evaporation, etc.) when p, T = constant, and $\lambda_{v,\,T}$ the corresponding quantity when v, T = constant, then we have the following equations:

$$\lambda_{p,\,T} = T(v_2 - v_1)\left(\frac{\partial p}{\partial T}\right)_{x,\,v}, \qquad (16)$$

$$\lambda_{v,\,T} = T(p_2 - p_1)\left(\frac{\partial v}{\partial T}\right)_{x,\,p}, \qquad (23)$$

where v_1, v_2 are the values of v at a given (p, T) when $x = 0$ and $x = 1$, respectively, and p_1, p_2 are the values of p at a given (v, T) when $x = 0$ and $x = 1$, respectively.

In order to have perfect continuity in the extensive quantities v, ϵ, entropy η, total heat h, etc., when passing from a single phase to a two-phase closed system, we define the quantities as follows:

$$v = V/M;\ \epsilon = E/M;\ \eta = \mathbf{H}/M;\ h = H/M;\ \text{etc.}, \qquad (41)$$

where V, E, $\mathbf{H}$, H, M, are the quantities for *entire* closed system under consideration.

II. SOME THERMODYNAMIC EQUATIONS.

Starting with Eq. (5), a set of equations can be developed similar to those of classic thermodynamics. For example,[3]

$$\left(\frac{\partial \epsilon}{\partial p}\right)_{v,\,T}\left(\frac{\partial p}{\partial v}\right)_{T,\,\epsilon}\left(\frac{\partial v}{\partial T}\right)_{\epsilon,\,p}\left(\frac{\partial T}{\partial \epsilon}\right)_{p,\,v} = 1, \qquad (42)$$

$$\left(\frac{\partial \epsilon}{\partial p}\right)_{T\ v}\left(\frac{\partial p}{\partial T}\right)_{v,\,\epsilon}\left(\frac{\partial T}{\partial v}\right)_{\epsilon,\,p}\left(\frac{\partial v}{\partial \epsilon}\right)_{p,\,T} = 1. \qquad (43)$$

[3] Reference: Wilson's "Advanced Calculus;" p. 127.

If one of the independent variables in Eq. (5), as for example p, is held constant,

$$\left(\frac{\partial \epsilon}{\partial v}\right)_{T,\ p}\left(\frac{\partial v}{\partial T}\right)_{\epsilon,\ p}\left(\frac{\partial T}{\partial \epsilon}\right)_{v,\ p} = -1. \tag{44}$$

Combining (42) and (44),

$$\left(\frac{\partial \epsilon}{\partial p}\right)_{v,\ T}\left(\frac{\partial p}{\partial v}\right)_{T,\ \epsilon} = -\left(\frac{\partial \epsilon}{\partial v}\right)_{T,\ p}. \tag{45}$$

If ϵ is replaced by η or any other calorimetric quantity, similar relations will be obtained.

For a reversible process (see previous paper, section II),

$$Td\eta = dQ = \left(\frac{\partial Q}{\partial v}\right)_{p,\ T} dv + \left(\frac{\partial Q}{\partial p}\right)_{T,\ v} dp + \left(\frac{\partial Q}{\partial T}\right)_{p,\ v} dT. \tag{46}$$

For a liquid-vapor system, the process indicated by $(\partial Q/\partial v)_{p,\ T}$ is obviously that of evaporation, where the latent heat $\lambda_{p,\ T}$ is involved. In the previous paper (section III) it is shown that a similar process may be realized where $\lambda_{p,\ T}$ will be the heat of dissociation. Therefore, for a system in one or two phases, where a single distinct transformation takes place, we have

$$\left(\frac{\partial Q}{\partial v}\right)_{p,\ T} = \frac{\lambda_{p,\ T}}{v_2 - v_1}. \tag{47}$$

Similarly,

$$\left(\frac{\partial Q}{\partial p}\right)_{T,\ v} = \frac{\lambda_{T,\ v}}{p_2 - p_1}. \tag{48}$$

Substituting these into (46), we have

$$Td\eta = \frac{\lambda_{p,\ T}}{v_2 - v_1} dv + \frac{\lambda_{T,\ v}}{p_2 - p_1} dp + \gamma dT, \tag{49}$$

where γ is defined by the equation $\gamma = (\partial Q/\partial T)_{p,\ v}$. The latter quantity is somewhat similar to $K = (dQ/dT)_x$ appearing in the previous paper, since they are both of the nature of a specific heat. Should we assume that when p, v = constant, the heat added will only increase the kinetic

and rotational energies of the molecules without causing any transformation, then x will be constant and γ and K will be identical.

A word must be said about Eqs. (47), (48) and (49). They apply to a system in which there occurs a single type of transformation. For example, if the system were water and its saturated vapor, we may assume the transformation to be represented by the reaction $(H_2O)_m \rightleftharpoons \frac{m}{n}(H_2O)_n$ where $m > n$; however, if the system consisted of only water vapor, then the reaction would be $(H_2O)_n \rightleftharpoons n(H_2O)$ or $H_2O \rightleftharpoons H_2 + \frac{1}{2}O_2$. We do not have to limit ourselves to molecular transformations, but we may consider also the ionization of a gas and all types of atomic transformations, provided however that one single type of transformation predominates and in the macroscopic sense, specific values of $\lambda_{p,T}$, $\lambda_{v,T}$, v_1, v_2, p_1, p_2 and γ are applicable to this single type. Cases where two or more types of transformations are macroscopically prominent will have to be left for later consideration.

Combining the first and second laws, we have

$$d\epsilon = Td\eta - pdv$$
$$= \left[\frac{\lambda_{p,T}}{v_2 - v_1} - p\right]dv + \frac{\lambda_{v,T}}{p_2 - p_1}dp + \gamma dT. \quad (50)$$

Also,

$$d\epsilon = \left(\frac{\partial \epsilon}{\partial v}\right)_{p,T} dv + \left(\frac{\partial \epsilon}{\partial p}\right)_{v,T} dp + \left(\frac{\partial \epsilon}{\partial T}\right)_{p,v} dT. \quad (51)$$

From (50) and (51),

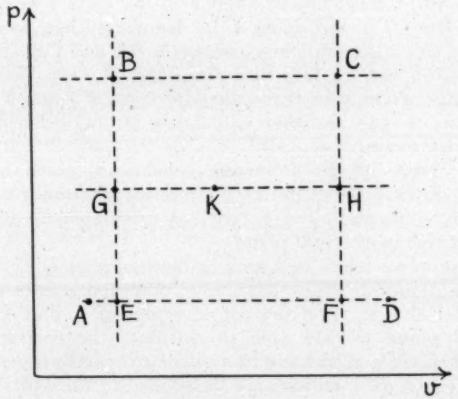
$$\left(\frac{\partial \epsilon}{\partial v}\right)_{p,T} = \frac{\lambda_{p,T}}{v_2 - v_1} - p; \left(\frac{\partial \epsilon}{\partial p}\right)_{v,T} = \frac{\lambda_{v,T}}{p_2 - p_1};$$
$$\left(\frac{\partial \epsilon}{\partial T}\right)_{p,v} = \gamma. \quad (52)$$

Similarly, from (49)

$$\left(\frac{\partial \eta}{\partial v}\right)_{p,T} = \frac{\lambda_{p,T}}{T(v_2 - v_1)}; \left(\frac{\partial \eta}{\partial p}\right)_{v,T} = \frac{\lambda_{v,T}}{T(p_2 - p_1)};$$
$$\left(\frac{\partial \eta}{\partial T}\right)_{p,v} = \frac{\gamma}{T}. \quad (53)$$

III. AN EXPLICIT EQUATION OF STATE FOR A SYSTEM WITH A SINGLE TYPE OF TRANSFORMATION.

Let us consider a closed system of one or two phases, which has a single type of transformation to which can be ascribed the macroscopic quantities $\lambda_{p,T}$, $\lambda_{v,T}$, etc. We shall assume that an equation of state must be of the form of Eq. (5), and for the particular transformation of the system Eqs. (52) and (53) must hold. Let us further assume $\lambda_{p,T}/(v_2 - v_1)$ to be a function of p, T only; also, assume $\lambda_{v,T}/(p_2 - p_1)$ to be a function of v, T only; and γ to be a



function of p, v only. Integrating (53) we may write

$$\eta = \frac{\lambda_{p,T}}{T(v_2 - v_1)} v + \Phi(p, T) = \frac{v}{T}\Gamma(p, T) + \Phi(p, T), \quad (54)$$

$$\eta = \frac{\lambda_{v,T}}{T(p_2 - p_1)} p + \Pi(v, T) = \frac{p}{T}\Theta(v, T) + \Pi(v, T), \quad (55)$$

$$\eta = \gamma \ln T + \psi(p, v). \quad (56)$$

If p, T = constant, we have in (54) a linear relation between η and v. In order to determine Γ and Φ at p, t = constant we need two sets of observations, say $A(\eta_A, p_A, v_A, T')$

and $D(\eta_D, p_A, v_D, T')$; see figure. From (54) we can calculate $\Gamma(p_A, T')$ and $\Phi(p_A, T')$, and then by calculation obtain the values of η for all other points on the isothermal-isopiestic AD.

Similarly, if we have two sets of observations $B(\eta_B, p_B, v_B, T')$ and $C(\eta_C, p_B, v_C, T')$ we can, by means of (54), calculate values of η for all other points on the isothermal-isopiestic BC.

Suppose we select the observed point B and the calculated point $E(\eta_E, p_A, v_B, T')$, (see figure); with these two points we may, in a manner similar to that above, calculate $\Theta(v_B, T')$ and $\Pi(v_B, T')$ from Eq. (55). Similarly, with the observed point C and the calculated point $F(\eta_F, p_A, v_C, T')$ we may calculate $\Theta(v_C, T')$ and $\Pi(v_C, T')$. Knowing these constants, we may calculate η for any points on BE and CF, as for example $G(\eta_G, p_G, v_B, T')$ and $H(\eta_H, p_G, v_C, T')$. With this knowledge we may in turn calculate $\Gamma(p_G, T')$ and $\Phi(p_G, T')$ by means of (54), and then calculate η for any other point on GH, as for example K.

We arrive at the following conclusion: given four observed points A, B, C and D, all in one isothermal plane, and where $p_A = p_D$ and $p_B = p_C$; we may calculate η for any other point in this isothermal plane.

Suppose we select two such isothermal planes, T' and T''; in each plane we shall have four observed points such as described above. For any set of values of p, v in each isothermal plane we are able to calculate the corresponding value of η. We then have two calculated points (η', p, v, T') and (η'', p, v, T''), which may be applied to Eq. (56) in order to determine the constants $\gamma(p, v)$ and $\psi(p, v)$. Knowing these constants, we may then compute η for any other temperature T at (p, v) by means of (56).

Starting with the linear relations (54), (55) and (56) the entire process involves algebraic calculations, which are simple but rather tedious. The resultant equation of state arrived at is:

$$\eta = a + bv + cp + dpv + (e + fv + gp + hpv) \ln T, \quad (57)$$

where the constants may be calculated from a selected set of observed points. (The details of these calculations are given in an appendix to this paper.) For a given system, this equation will apply to the portion of the (p, v, T) space

bounded by $x = 0$ and $x = 1$. Outside of this region there would be a different type of transformation and therefore the constants in (57) would necessarily be different.

From (53) and (57) we have for the latent heats

$$\lambda_{p,\,T} = T(v_2 - v_1)[b + dp + (f + hp) \ln T], \quad (58)$$

$$\lambda_{v,\,T} = T(p_2 - p_1)[c + dv + (g + hv) \ln T] \quad (59)$$

and

$$\gamma = (e + fv + gp + hpv). \quad (60)$$

An expression for the internal energy ϵ may be obtained as follows:

$$\begin{aligned}
\epsilon &= \int \left[\left(\frac{\partial \epsilon}{\partial v}\right)_{p,\,T} \delta v + \left(\frac{\partial \epsilon}{\partial p}\right)_{v,\,T} \delta p + \left(\frac{\partial \epsilon}{\partial T}\right)_{p,\,v} \delta T \right] \\
&= \int T \left[\left(\frac{\partial \eta}{\partial v}\right)_{p,\,T} \delta v + \left(\frac{\partial \eta}{\partial p}\right)_{v,\,T} \delta p \right. \\
&\qquad \left. + \left(\frac{\partial \eta}{\partial T}\right)_{p,\,v} \delta T \right] - \int p \delta v \\
&= \int T \delta \eta - pv = \int \delta(T\eta) - \int \eta \delta T - pv \\
&= T\eta - pv - (a + bv + cp + dpv)T \\
&\qquad - (e + fv + gp + hpv)(T \ln T - T) + \text{constant} \\
&= -pv + (e + fv + gp + hpv)T + \text{constant}. \quad (61)
\end{aligned}$$

The integral $\int p \delta v = pv$ because p, v are independent variables in these considerations. For the total heat, we have from (61)

$$H = \epsilon + pv = (e + fv + gp + hpv)T + \text{constant}. \quad (62)$$

Starting with Eq. (52) and following the same analysis, we can derive an equation of state for ϵ similar to (57),

$$\epsilon = a_1 + b_1 v + c_1 p + d_1 pv + (e_1 + f_1 v + g_1 p + h_1 pv)T, \quad (63)$$

where the constants are related to the 8 experimentally observed points.

IV. EXPERIMENTAL VERIFICATION OF THE EQUATION OF STATE.

Equation (57) should hold for the "meta-stable" states as well as the ordinary stable states. To verify this equation

completely, we must have sets of experimentally observed values of η, p, v, T over the entire region from $x = 0$ to $x = 1$. The writer has been unable to find such sets for the "metastable" states in the literature. The data are very meagre, and what values do exist have been obtained by calculation on the basis of some equation involving but two independent variables.

However, Eq. (57) should also apply to the restricted set of "stable" states, for which we have sufficient data, and the writer has selected the data on ammonia and steam, substances which have been studied very extensively. For ammonia, the calculations are based on the tables published by the National Bureau of Standards.[4] For steam, the recent steam tables of Keenan and Keyes[5] were used. From this data we should have a partial verification of the equation of state.

For each substance, the liquid and its saturated vapor were considered as one system, involving a single type of transformation. Calculations were made also on the superheated vapor, on the assumption that in this case a single transformation exists without change of type over the entire experimental range of p, v, T.

For saturated ammonia the following constants of Eq. (57) were obtained:

$$a = -6.323{,}79. \qquad e = +1.046{,}87.$$
$$b = -0.666{,}0. \qquad f = +0.112{,}92.$$
$$c = +0.0_3398{,}2. \qquad g = -0.0_463{,}12.$$
$$d = +0.032{,}80 \qquad h = -0.004{,}761.$$

These were obtained by solving simultaneous equations of the form of (57), using 8 sets of values from the ammonia tables, indicated in Table I by stars. In this table the calculated and tabulated values for η and $\lambda_{p,T}$ are compared. The results are given alternately for saturated liquid and saturated vapor. On the average, the agreement is good to about 0.3 per cent. The values of H, calculated from Eq. (62), are given in the

[4] "Tables of Thermodynamic Properties of Ammonia," Circular of the Bureau of Standards, No. 142; Apr. 16, 1923.

[5] "Thermodynamic Properties of Steam" by J. H. Keenan and F. G. Keyes· 1936; Publishers—John Wiley and Sons.

second column of Table II. Since the ammonia tables assume $H = 0$ for saturated liquid at $-40°$ F, this value is indicated in the column as H_0, and the constant of Eq. (60) is taken equal to $-H_0$. In the third and fourth columns of Table II are given the calculated values of $(H - H_0)$ in B.t.u. per lb.

TABLE I.

Entropy and Latent Heat ($\lambda_{p,T}$) for Saturated Ammonia.

	t °F.	p lbs./in.²	v ft.³/lb.	η B.t.u./lb. °F.		$\lambda_{p,T}$ B.t.u./lb.	
				Calculated.	From Table.	Calculated.	From Table.
(1)*	−60.	5.55	.02278	−.0517	−.0517		
(2)*	−60.	5.55	44.73	1.4769	1.4769	610.8	610.8
(3)	−40.	10.41	.02322	.0001	.0000		
(4)	−40.	10.41	24.86	1.4426	1.4242	605.3	597.6
(5)	−20.	18.30	.02369	.0497	.0497		
(6)	−20.	18.30	14.68	1.3864	1.3774	587.7	583.6
(7)*	0.	30.42	.02419	.0975	.0975		
(8)*	0.	30.42	9.116	1.3352	1.3352	568.8	568.9
(9)	20.	48.21	.02474	.1437	.1437		
(10)	20.	48.21	5.910	1.2939	1.2969	551.6	553.1
(11)	40.	73.32	.02533	.1885	.1885		
(12)	40.	73.32	3.971	1.2594	1.2618	535.0	536.2
(13)*	60.	107.6	.02597	.2322	.2322		
(14)*	60.	107.6	2.751	1.2294	1.2294	518.1	518.1
(15)	80.	153.0	.02668	.2748	.2749		
(16)	80.	153.0	1.955	1.2008	1.1991	499.5	498.7
(17)	100.	211.9	.02747	.3166	.3166		
(18)	100.	211.9	1.419	1.1729	1.1705	479.3	477.8
(19)*	120.	286.4	.02836	.3576	.3576		
(20)*	120.	286.4	1.047	1.1427	1.1427	455.2	455.0
(21)	140.	379.1	.02938	.3979	—		
(22)	140.	379.1	.8480x	—	—	464.2	(430.)
(23)	190.	708.9	.03281	.4964	—		
(24)	190.	708.9	.4610x	—	—	405.7	(351.)
(25)c	271.4	1657.0	.0686	.7146	—	0.0	0.

* Points used in calculating constants of Eq. (57).

x Not given in table, but calculated on basis of perfect gas law.

c Critical point.

( ) in last column are extrapolations beyond the range of measurements.

for the saturated vapor and saturated liquid, respectively. In the fifth column, the calculated values of $\lambda_{p,T}$ (Table I) are added to $(H - H_0)$ of column 4, giving a second set of calculated values for the total heat of saturated vapor. In the last column are given $(H - H_0)$ for both the liquid and vapor as taken from the ammonia tables.

Comparing the values of columns 4 and 5 with those in the last column, the agreement is reasonably good, although not at all comparable to the agreement shown in Table I. However, the discrepancy between the values in column 3 and the last column is disappointing. This matter will be discussed below.

TABLE II.

Total Heat H for Saturated Ammonia.

	$t°$ F.	Calculated—B.t.u./lb.				From Table $(H-H_0)$.
		H.	$(H-H_0)_{sat.vap.}$	$(H-H_0)_{sat.lig.}$	$(H-H_0)_{sat.lig.}+\lambda_{p,\ T(calc.)}$	
(1)*	−60.	418.97		− 20.62		−21.18
(2)*	−60.	1964.22	1524.63		590.2	589.6
(3)	−40.	439.59 = H_0		0.00		0.00
(4)	−40.	1099.87	660.28		605.3	597.6
(5)	−20.	459.95		20.36		21.36
(6)	−20.	626.16	186.57		608.1	605.0
(7)*	0.	479.88		40.29		42.92
(8)*	0.	346.59	− 93.00		609.1	611.8
(9)	20.	499.21		59.62		64.71
(10)	20.	170.14	−269.45		611.2	617.8
(11)	40.	517.70		78.11		86.77
(12)	40.	52.23	−387.36		613.1	623.0
(13)*	60.	535.02		95.43		109.18
(14)*	60.	− 30.39	−469.89		613.5	627.3
(15)	80.	550.80		111.21		131.99
(16)	80.	− 89.59	−529.18		610.7	630.7
(17)	100.	564.55		124.96		155.21
(18)	100.	−133.04	−572.63		604.3	633.0
(19)*	120.	575.71		136.12		178.98
(20)*	120.	−162.59	−602.18		591.3	634.0
(21)	140.	583.53		143.94		(203.)
(22)	140.	−246.88	−686.47		608.1	
(23)	190.	581.44		141.85		(269.)
(24)	190.	−325.85	−765.44		547.6	
(25)c	271.4	298.88		−140.71		(433.)

* Points used in calculating constants of Eq. (57).

c Critical point.

For saturated steam, the following constants of Eq. (57) were obtained:

$$a = -6.149{,}6. \qquad e = +0.992{,}4.$$
$$b = -0.430{,}8. \qquad f = +0.068{,}08.$$
$$c = +0.0_3105{,}90. \qquad g = -0.0_414{,}961.$$
$$d = +0.026{,}59. \qquad h = -0.003{,}639.$$

The calculated and tabulated values for η and $\lambda_{p,\,T}$ for saturated steam are given in Table III. The agreement for η is on the average about 2 per cent. and for $\lambda_{p,\,T}$ about 4 per cent., which is reasonably good, considering that it covers the entire saturated dome and that the constants are based on 8 points arbitrarily selected. The calculated and tabular

TABLE III.

Entropy and Latent Heat ($\lambda_{p,\,T}$) for Saturated Steam.

	t °F.	p lbs./in².	v ft³./lb.	η B.t.u./lb. °F.		$\lambda_{p,\,T}$ B.t.u./lb.	
				Calculated.	From Table.	Calculated.	From Table.
(1)*	130.	2.221	.01625	0.1819	0.1816		
(2)*	130.	2.221	157.64	1.9096	1.9104	1017.1	1020.0
(3)	160.	4.739	.01639	0.2313	0.2312		
(4)	160.	4.739	77.40	1.9313	1.8479	1052.0	1002.3
(5)	190.	9.336	.01656	0.2776	0.2785		
(6)	190.	9.336	41.01	1.8461	1.7929	1017.1	984.1
(7)*	250.	29.82	.01698	0.3674	0.3675		
(8)*	250.	29.82	13.824	1.6992	1.6995	945.0	945.5
(9)	300.	67.01	.01742	0.4368	0.4370		
(10)	300.	67.01	6.464	1.6276	1.6345	905.0	910.1
(11)*	360.	153.01	.01810	0.5159	0.5160		
(12)*	360.	153.01	2.954	1.5670	1.5673	862.5	862.2
(13)	400.	247.25	.01865	0.5668	0.5668		
(14)	400.	247.25	1.8608	1.5301	1.5270	829.4	826.0
(15)*	460.	466.94	.0196	0.6413	0.6407		
(16)*	460.	466.94	.9927	1.4700	1.4696	763.6	763.2
(17)	520.	812.72	.0210	0.7146	0.7158		
(18)	520.	812.72	.5557	1.3962	1.4121	672.6	686.4
(19)	600.	1544.6	.0241	0.8112	0.8198		
(20)	600.	1544.6	.2642	1.2830	1.3316	506.5	548.5
(21)	700.	3096.4	.0394	0.9667	1.0117		
(22)	700.	3096.4	.0747	1.0677	1.1471	130.1	172.1
(23)c	705.4	3206.2	.0503	1.0046	1.0580		
(24)	32.	0.8854	.01602	0.0009	0.0000		

* Points used in calculating constants of Eq. (57).

c Critical point.

values for total heat of saturated steam are given in Table IV. This table is arranged like Table III; the agreements and differences are characteristically similar to those for saturated ammonia.

If we compare the corresponding constants of Eq. (57) for saturated ammonia and saturated steam, it will be interesting to note that they are of the same order of magnitude and of

the same sign. If there is any validity to the theory on which Eq. (57) is based, it is not inconceivable that the constants may serve as a measure of certain characteristics of the molecules and their associations.

The calculations for the total heat are rather puzzling. The values of H for the saturated liquid, as calculated from Eq. (62), are in moderately good agreement with the tables, whereas for the saturated vapor the discrepancies are large. Nevertheless, if we combine the values of $H_{liq.}$ and $\lambda_{p,\ T}$ (both of which are basically results of Eq. (57)) to form the calculated $H_{vap.}$ for saturated vapor, the agreement with the tabular values is fairly good.

For superheated ammonia and superheated steam, the calculations were carried out on the assumption that in each

TABLE IV.

Total Heat H for Saturated Steam.

	t °F.	Calculated—B.t.u./lb.				From Table $(H-H_0)$.
		H.	$(H-H_0)_{sat.vap.}$	$(H-H_0)_{sat.lig.}$	$(H-H_0)_{sat.lig.}+\lambda_{p,\ T(calc.)}$	
(1)	32.	$488.35=H_0$		0.00		0.0
(2)*	130.	585.65		97.30		97.9
(3)*	130.	6161.16	5672.81		1114.4	1117.9
(4)	160.	615.34		126.99		127.9
(5)	160.	3052.50	2564.15		1179.0	1130.2
(6)	190.	644.92		156.57		158.0
(7)	190.	1553.01	1064.66		1173.7	1142.0
(8)*	250.	703.39		215.04		218.5
(9)*	250.	307.13	− 181.22		1160.0	1164.0
(10)	300.	750.72		262.37		268.6
(11)	300.	−110.07	− 598.42		1167.4	1179.7
(12)*	360.	804.22		315.87		332.2
(13)*	360.	−371.85	− 860.20		1178.4	1194.4
(14)	400.	836.53		348.18		375.0
(15)	400.	−480.50	− 968.85		1177.6	1201.0
(16)*	460.	876.76		388.41		441.4
(17)*	460.	−582.95	−1071.30		1152.0	1204.6
(18)	520.	900.78		412.43		511.9
(19)	520.	−612.76	−1101.11		1085.0	1198.2
(20)	600.	885.24		396.89		617.0
(21)	600.	−527.51	−1015.86		903.4	1165.5
(22)	700.	585.32		96.97		823.3
(23)	700.	126.85	− 361.50		227.1	995.4
(24)c	705.4	420.49		−67.86		902.7

* Points used in calculating constants of Eq. (57).

c Critical point.

TABLE V.

Superheated Ammonia.

	t °F.	p lbs./in².	v ft³./lb.	η B.t.u./lb. °F.	
				Calculated.	From Table.
(1)*	130.	125.	2.780	1.2899	1.2899
(2)*	300	150	3.095	1.4157	1.4157
(3)*	200	70	5.807	1.4302	1.4302
(4)*	80	40	8.268	1.3900	1.3900
(5)*	300	42	11.31	1.5708	1.5708
(6)*	170	25	15.73	1.5305	1.5303
(7)*	30	13	23.43	1.4779	1.4779
(8)*	200	13	31.85	1.6328	1.6328
(9)	150	250	1.352	1.1446	1.2078
(10)	230	210	1.942	1.2325	1.3143
(11)	70	70	4.509	1.3446	1.3054
(12)	300	80	5.894	1.5075	1.4933
(13)	200	40	10.27	1.4969	1.4987
(14)	20	23	12.80	1.3793	1.3961
(15)	220	20	21.30	1.5893	1.5978
(16)	100	16	21.84	1.5309	1.5218
(17)	380	250	2.038	1.4617	1.4111
(18)	−20	6	45.73	1.6434	1.5166
(19)	120	7	52.00	1.7408	1.6382
(20)	220	120	3.442	1.3611	1.3793

* Points used in calculating constants of Eq. (57).

case there is a single transformation. The particular mechanism of the transformation is not considered; it may be a complete breaking up of the molecule or merely a change from one degree of polymerization to a simpler form. The following are the constants of Eq. (57) for these states:

	Superheated Ammonia.	Superheated Steam.
a	−31.492,2	+0.844,49
b	+ 0.125,86	−0.005,089,8
c	− 0.077,90	−0.001,210,0
d	− 0.092,84	−0.000,455,1
e	+ 6.686,3	+0.124,87
f	− 0.018,860	+0.000,893,8
g	+ 0.011,184	+0.000,144,64
h	+ 0.010,461	+0.000,091,448

In Tables V and VI the calculated and tabulated values of entropy for the superheated regions, covering the entire range of each table, are compared. In the case of steam, it was thought that there might be a difference in the form of transformation for states below and above the critical temperature,

and if calculations were limited to states, say, below the critical temperature the agreement might be better than that shown in Table VI. However, this did not prove to be true.

Considering the range of pressures and temperatures which are covered for each substance, the agreement for η as shown in Tables V and VI is reasonably good. Attempts were made to calculate $\lambda_{p,\,T}$ for the superheated regions, using Eq. (58) as a basis. The difficulties here are to determine $(v_2 - v_1)$, which requires a knowledge of the mechanism of the transformation in question. We do not know whether, in the superheated region covered by the respective tables, the transformation is of a single type or whether there are several types which are prominent macroscopically. In all likelihood the latter condition prevails, and changes in polymerization as well as in dissociation may be occurring. Calculations of $\lambda_{p,\,T}$ have yielded values quite different from experimentally observed heats of dissociation. Calculations of H on the basis of Eq. (62) have also been disappointing.

TABLE VI.

Superheated Steam.

	t °F.	p lbs./in^2.	v ft^3./lb.	η B.t.u./lb. °F.	
				Calculated.	From Table.
(1)	200	1.	392.6	1.9890	2.0512
(2)	300	4.	112.88	1.8348	1.9618
(3)*	400	3.	170.54	1.9327	2.0507
(4)*	400	60.	8.357	1.7638	1.7135
(5)	500	1.	571.6	2.3994	2.2233
(6)	600	4.	157.73	2.0075	2.1173
(7)	600	80.	7.797	1.8204	1.7836
(8)	600	1000.	0.5140	1.6059	1.4450
(9)	500	30.	18.933	1.8134	1.8464
(10)	500	400.	1.2851	1.7054	1.5281
(11)*	700	10.	69.01	1.9389	2.0596
(12)*	700	1000.	0.6084	1.6525	1.5141
(13)	720	3500.	0.0557	1.1107	1.0918
(14)	800	6.	125.01	2.0442	2.1566
(15)	800	300.	2.442	1.8306	1.7184
(16)	800	4000.	0.1052	1.1092	1.2757
(17)*	900	30.	26.95	1.9425	2.0169
(18)*	900	2000.	0.3532	1.5576	1.5139
(19)*	1100	50.	18.550	1.9842	2.0308
(20)*	1100	2000.	0.4311	1.6573	1.6012

* Points used in calculating constants of Eq. (57).

V. CONCLUSIONS.

For a complete verification of the above theory, and particularly of Eq. (57), it would be necessary to have experimental data on the "meta-stable" states for ammonia and steam. The experimental work involved in obtaining simultaneous sets of values of η, p, v, and T for these states should be much simpler than for the "stable" states. The reason is that in experimental work on the determination of the thermodynamic properties of a system, the principal sources of error arise when the system is not in "stable" equilibrium. Material systems tend very readily to the "meta-stable" states, and the experimenter finds it necessary to app y proper stirring to avoid supersaturated states, and to add catalytic agents to bring reactants to what he considers the proper state. In the present instance we can experiment on a closed system, whose volume and mass we know. Starting with a known state, i.e., that of "stable" equilibrium, we may add or remove a measured quantity of heat, and then take great care not to disturb the system by any outside agent (mechanical, thermal, chemical, radiant, etc.) while the system settles down to equilibrium. When the system has reached this state, measurements of $\Delta\eta$, p, v, T can be made, and the process continued to a new point in the p, v, T space.

In low temperature work, where supersaturation may very readily occur because of the difficulty in stirring the system, many discrepancies might be explained by considering the system from the viewpoint of this larger assemblage of states.

In the introduction to the first paper, the writer stated that because of the difficulties encountered in extending the mass-action law and the gas laws to condensed systems, the present approach was in the reverse order—to formulate a theory as to the behavior of condensed systems and then to extend it to rarefied systems. It is interesting to examine the evidence on ammonia and steam as it throws light on this viewpoint. We find that the data on the saturated states fall in quite well with Eqs. (57) and (58) which would seem to imply that the transformation from the liquid to the saturated vapor is of a single, distinct type. However, the superheated states appear to be much more complex from this thermodynamic standpoint. In all probability we may find them

to be the result of several types of transformations which take place simultaneously. The possible complexity of such states is considered in the previous paper under section VI (endothermic and exothermic reactions), where the several types of reactions may make the system extremely complex for thermodynamic analysis.

Further studies would have to consider the effect of several transformations existing simultaneously within the same system.

SUMMARY.

This paper is a continuation of a previous paper published in this JOURNAL. The basic idea in the two papers is to enlarge the assemblage of thermodynamic states by including the so-called "metastable" states. Considering a system, in one or two phases, which has a single type of transformation, the writer develops an equation of state of the form $\eta = a + bv + cp + dpv + (e + fv + gp + hpv) \ln T$, where p, v, T are three independent variables, and a, b, c, etc. are constants. The latent heat at p, T = constant is

$$\lambda_{p,T} = T(v_2 - v_1)[b + dp + (f + hp) \ln T],$$

which is derived from the equation of state.

The available thermodynamic data on ammonia and steam are used to check these equations. It is found that within the saturated region the agreement is quite satisfactory, whereas for the superheated region the agreement is not so good.

APPENDIX.

Derivation of Equation of State.

Equation (57) may be derived in the following manner. We begin with the equations

$$\eta = \frac{v}{T}\Gamma(p, T) + \Phi(p, T), \tag{54}$$

$$\eta = \frac{p}{T}\Theta(v, T) + \Pi(v, T), \tag{55}$$

$$\eta = \gamma \ln T + \psi(p, v). \tag{56}$$

Referring to the above figure in which the observed sets of points A, B, C and D are all at the same temperature T', we have

$$\eta_A = \frac{v_A}{T'}\Gamma(p_A, T') + \Phi(p_A, T'), \tag{64}$$

$$\eta_D = \frac{v_D}{T'}\Gamma(p_A, T') + \Phi(p_A, T'). \tag{65}$$

Solving these, we have

$$\Gamma(p_A, T') = T'\frac{\eta_D - \eta_A}{v_D - v_A}; \qquad \Phi(p_A, T') = \frac{\eta_A v_D - \eta_D v_A}{v_D - v_A}. \tag{66}$$

Therefore, along AD,

$$\eta = v\cdot\frac{T'}{T}\cdot\frac{\eta_D - \eta_A}{v_D - v_A} + \frac{\eta_A v_D - \eta_D v_A}{v_D - v_A} \tag{67}$$

Similarly, along BC,

$$\eta = v\cdot\frac{T'}{T}\cdot\frac{\eta_C - \eta_B}{v_C - v_B} + \frac{\eta_B v_C - \eta_C v_B}{v_C - v_B}. \tag{68}$$

Using Eq. (67), we have at $E(\eta_E, p_A, v_B, T')$

$$\eta_E = \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A}. \tag{69}$$

Similarly, at $F(\eta_F, p_A, v_C, T')$ we have

$$\eta_F = \frac{\eta_A(v_D - v_C) + \eta_D(v_C - v_A)}{v_D - v_A}. \tag{70}$$

Referring now to Eq. (55); using the experimentally observed point B and the calculated point E, we have

$$\eta_B = \frac{p_B}{T'}\Theta(v_B, T') + \Pi(v_B, T'), \tag{71}$$

$$\eta_E = \frac{p_A}{T'}\Theta(v_B, T') + \Pi(v_B, T'). \tag{72}$$

Solving these equations, we have

$$\Theta(v_B, T') = \frac{T'}{p_B - p_A} \times \left[\eta_B - \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A} \right], \quad (73)$$

$$\Pi(v_B, T') = \eta_B - \frac{p_B}{p_B - p_A} \times \left[\eta_B - \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A} \right]. \quad (74)$$

At $G(\eta_G, p_G, v_B, T')$ we have

$$\eta_G = \frac{p_G}{T'} \Theta(v_B, T') + \Pi(v_B, T')$$

$$= \eta_B - \frac{p_B - p_G}{p_B - p_A} \times \left[\eta_B - \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A} \right]. \quad (75)$$

Using Eq. (55) with points C and F, we have

$$\eta_C = \frac{p_B}{T'} \Theta(v_C, T') + \Pi(v_C, T'), \quad (76)$$

$$\eta_F = \frac{p_A}{T'} \Theta(v_C, T') + \Pi(v_C, T'). \quad (77)$$

Solving, we have

$$\Theta(v_C, T') = \frac{T'}{p_B - p_A} \times \left[\eta_C - \frac{\eta_A(v_D - v_C) + \eta_D(v_C - v_A)}{v_D - v_A} \right], \quad (78)$$

$$\Pi(v_C, T') = \eta_C - \frac{p_B}{p_B - p_A} \times \left[\eta_C - \frac{\eta_A(v_D - v_C) + \eta_D(v_C - v_A)}{v_D - v_A} \right]. \quad (79)$$

At point H we have

$$\eta_H = \frac{p_G}{T'}\Theta(v_C, T') + \Pi(v_C, T')$$

$$= \eta_C - \frac{p_B - p_G}{p_B - p_A} \times \left[\eta_C - \frac{\eta_A(v_D - v_C) + \eta_D(v_C - v_A)}{v_D - v_A}\right]. \quad (80)$$

Using Eq. (54) along GH, we have

$$\eta_G = \frac{v_B}{T'}\Gamma(p_G, T') + \Phi(p_G, T'), \quad (81)$$

$$\eta_H = \frac{v_C}{T'}\Gamma(p_G, T') + \Phi(p_G, T'). \quad (82)$$

Solving and simplifying terms we have

$$\Gamma(p_G, T') = T'\left[\frac{p_G - p_A}{p_B - p_A} \cdot \frac{\eta_C - \eta_B}{v_C - v_B} - \frac{p_B - p_G}{p_B - p_A} \cdot \frac{\eta_A - \eta_D}{v_D - v_A}\right], \quad (83)$$

$$\Phi(p_G, T') = \eta_B - \frac{p_B - p_G}{p_B - p_A} \times \left[\eta_B - \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A}\right] - v_B\left[\frac{p_G - p_A}{p_B - p_A} \cdot \frac{\eta_C - \eta_B}{v_C - v_B} - \frac{p_B - p_G}{p_B - p_A} \cdot \frac{\eta_A - \eta_D}{v_D - v_A}\right]. \quad (84)$$

Therefore, for any point on GH, such as K, we have

$$\eta = (v - v_B)\left[\frac{p_G - p_A}{p_B - p_A} \cdot \frac{\eta_C - \eta_B}{v_C - v_B} - \frac{p_B - p_G}{p_B - p_A} \cdot \frac{\eta_A - \eta_D}{v_D - v_A}\right] + \eta_B - \frac{p_B - p_G}{p_B - p_A}\left[\eta_B - \frac{\eta_A(v_D - v_B) + \eta_D(v_B - v_A)}{v_D - v_A}\right]. \quad (85)$$

The line GH is at an arbitrarily selected pressure. Therefore,

we can place $p_G = p$; the coördinates of K are then $K(\eta, p, v, T')$. Expanding and collecting the terms in (85) we have the final form,

$$\eta = Q_0 + Q_1 v + Q_2 p + Q_3 pv, \tag{86}$$

where

$$Q_0 = \frac{1}{p_B - p_A}\left[p_A v_B \frac{\eta_C - \eta_B}{v_C - v_B} + p_B v_B \frac{\eta_A - \eta_D}{v_D - v_A} + p_B \eta_A \frac{v_D - v_B}{v_D - v_A} + p_B \eta_D \frac{v_B - v_A}{v_D - v_A} - p_A \eta_B \right], \tag{87}$$

$$Q_1 = -\frac{1}{p_B - p_A}\left[p_A \frac{\eta_C - \eta_B}{v_C - v_B} + p_B \frac{\eta_A - \eta_D}{v_D - v_A} \right], \tag{88}$$

$$Q_2 = -\frac{1}{p_B - p_A}\left[v_B \left(\frac{\eta_C - \eta_B}{v_C - v_B} + \frac{\eta_A - \eta_D}{v_D - v_A} \right) - \eta_B + \eta_A \frac{v_D - v_B}{v_D - v_A} + \eta_D \frac{v_B - v_A}{v_D - v_A} \right], \tag{89}$$

$$Q_3 = \frac{1}{p_B - p_A}\left[\frac{\eta_C - \eta_B}{v_C - v_B} + \frac{\eta_A - \eta_D}{v_D - v_A} \right]. \tag{90}$$

We have thus proved that, given the four observed points A, B, C, D, all in one isothermal plane, and where $p_A = p_D$, $p_B = p_C$, we may calculate η for any other point in this isothermal plane by means of Eq. (86).

For the two points (p, v, T') and (p, v, T'') we will have, from (86),

$$\eta' = Q_0' + Q_1' v + Q_2' p + Q_3' pv, \tag{91}$$

$$\eta'' = Q_0'' + Q_1'' v + Q_2'' p + Q_3'' pv, \tag{92}$$

where the constants Q_0', Q_1', etc. are given by (87) to (90), inclusive, for $T = T'$, and the constants Q_0'', Q_1'', etc. are given by the same equations for $T = T''$. Introducing (91) and (92) into (56), we have

$$\gamma(p, v) = \frac{\eta'' - \eta'}{\ln (T''/T')} = \frac{1}{\ln (T''/T')}[(Q_0'' - Q_0') + v(Q_1'' - Q_1') + p(Q_2'' - Q_2') + pv(Q_3'' - Q_3')], \tag{93}$$

$$\psi(p, v) = Q_0' + Q_1'v + Q_2'p + Q_3'pv - \frac{\ln T'}{\ln (T''/T')}[(Q_0'' - Q_0') + v(Q_1'' - Q_1') + p(Q_2'' - Q_2') + pv(Q_3'' - Q_3')]. \quad (94)$$

Therefore, (56) becomes, on substitution,

$$\eta = a + bv + cp + dpv + (e + fv + gp + hpv) \ln T, \quad (95)$$

where

$$a = Q_0' - (Q_0'' - Q_0')\frac{\ln T'}{\ln (T''/T')}; \qquad b = Q_1' - (Q_1'' - Q_1')\frac{\ln T'}{\ln (T''/T')}$$

$$c = Q_2' - (Q_2'' - Q_2')\frac{\ln T'}{\ln (T''/T')}; \qquad d = Q_3' - (Q_3'' - Q_3')\frac{\ln T'}{\ln (T''/T')}$$

$$e = \frac{Q_0'' - Q_0'}{\ln (T''/T')}; \qquad f = \frac{Q_1'' - Q_1'}{\ln (T''/T')};$$

$$g = \frac{Q_2'' - Q_2'}{\ln (T''/T')}; \qquad h = \frac{Q_3'' - Q_3'}{\ln (T''/T')}. \quad (96)$$

The Ortho-Krome Process of Coating Paper.—(*Paper Trade Journal*, Vol. 109, No. 16.) A. B. HURLEY presented a paper at the Annual Meeting of the Technical Association of the Pulp and Paper Industry on this subject in which there is mentioned three things necessary for good vision—the light source, the surface of the object being viewed and the eye itself. The optician can keep our eyes in good condition, the physicist has given us improved artificial light and is working to perfect its quality, and consideration of surface is equally important. In this latter direction, the Ortho-Krome process of coating paper is a contribution not only to better seeing but in enhancing the appearance of the sheet with the added advantage of prolonging life of the surface. This process consists in applying a very thin coating of fine pigments similtaneously and rapidly to both sides of the paper in a manner similar to off-set printing. The coating, unlike the clay casein coating ordinarily used, is more like a water color printing ink. It is preferable, because of opacity, color, and softness, to use zinc sulphide or its lithopones as the dry pigment. A binder is necessary. Added to the mixture of pigment and binder are pure colors selected to modify and control the light reflected from the surface of the paper. A heavy coating on the paper is not desirable and every mechanical means of getting a thin continuous film on the surface is incorporated in the coating machine. To minimize the amount of coating used, only about 50 per cent. of the surface of the paper is covered and the plate cylinders in the machine are etched in the manner of a half-tone to accomplish this. Furthermore, this half-tone effect is important, if not essential, to other particular features of this process. The minimum amount of coating on both sides of a ton of 45 lb. basis book paper would be approximately 80 lb.

R. H. O.

THE POROUS STRUCTURE OF PAPER IN RELATION TO DRYING AND IMPREGNATION.

BY

D. A. McLEAN AND G. T. KOHMAN,

Bell Telephone Laboratories.

INTRODUCTION.

In a recent publication,[1] a method was described for preparing impregnated paper samples of various moisture contents. This method consists of submerging prehumidified samples of paper in molten impregnant which is then held at a fixed temperature and fixed pressure until the evolution of moisture virtually ceases. The lower the pressure maintained at a given temperature, the lower the final moisture content. Although very little moisture continues to come off after an hour or two, a period of 16 hours was allowed for equilibrium.

Certain observations made in the course of this work are interesting and of far-reaching importance, and have led to further extensive work which it was beyond the scope of the previous paper to describe.

In the first place it was always noted that the final moisture content was far higher than would be predicted from the desorption isotherm for paper at the temperature and pressure employed. This discrepancy extends down to zero pressure since evacuation to a fraction of a millimeter at 120° C. failed to reduce the moisture content below approximately 1 per cent, based on the dry weight of the paper.

This discrepancy is clearly illustrated in Fig. 1 which makes use of the data obtained in the previous work. As ordinates are plotted the pressures used to obtain the residual moisture contents indicated in parentheses. As abscissæ are plotted the pressures corresponding to these moisture contents

[1] D. A. McLean and G. T. Kohman, "The Influence of Moisture Upon the D.C. Conductivity of Impregnated Paper," Jl. Franklin Inst., **226**, 203 (1938).

as read from the adsorption isotherm. For this isotherm the data of Urquhart and Williams [2] on cotton were extrapolated to 120° C. and the adsorption and desorption isotherms were considered to be coincident which at these temperatures is a fair approximation.

The regularity with which results of this nature have been obtained has led to an attempt to evolve a theory adequate to explain them.

THEORY.

Since paper is a typical porous material which is readily wetted by the common impregnants and other organic liquids, it is to be expected that contact of liquid impregnant with paper would be accompanied by entrance of the liquid into the porous structure until capillary forces are balanced by the pressure of compressed gases and vapors within the pores. The pressure on these gases and vapors will exceed the pressure in the surrounding medium by the capillary force $\frac{2\lambda \cos \Theta}{R}$, where λ is the surface tension of the impregnant, Θ the contact angle impregnant-paper, and R is the effective pore radius in the paper. Previous work has shown that cos Θ can be taken as unity without serious error.[3, 4, 5] In any attempt to remove moisture from paper immersed in a low vapor pressure liquid such as the impregnants commonly used in electrical work, the first moisture evolved will sweep out most of the entrapped air, after which the water vapor in the pores will be subjected to a pressure of $P_1 + \frac{2\lambda}{R}$, where P_1 is the pressure maintained in the surrounding medium. If P_2 corresponds to the pressure within the pores which is equivalent to the equilibrium desorption isotherm pressure, it follows at once that $P_2 = P_1 + \frac{2\lambda}{R}$.

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[2] Urquhart and Williams, *Textile Inst. Jl.*, **15**, 559T (1924).

[3] R. L. Peek, Jr., and D. A. McLean, *Ind. & Eng. Chem.* (*Anal Ed.*), **6**, 85 (1934).

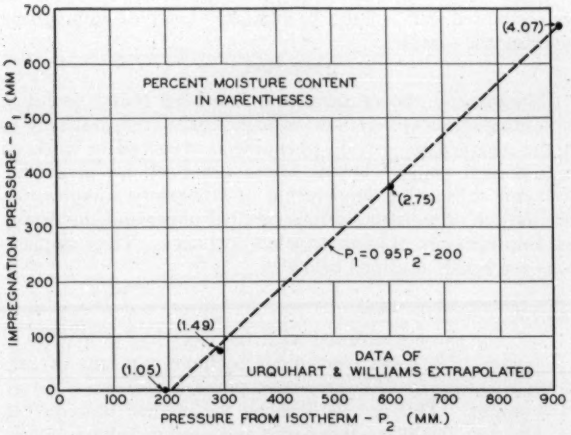
[4] D. A. McLean and G. T. Kohman, *El. Eng.*, **53**, 225 (1934).

[5] C. J. Frosch, *Physics*, **7**, 167 (1936).

The direct consequence of this simple theory is that when paper containing water is evacuated under a low vapor pressure liquid, its final equilibrium moisture content will not correspond to P_1, the pressure maintained external to the sample, but to a pressure $\frac{2\lambda}{R}$ greater than this.

Figure 1 as plotted provides a direct test of this relation-

FIG. 1.



Relation between impregnation pressure and pressure from sorption isotherm corresponding to resulting moisture content.

ship. From this figure, P_1 is seen to be a linear function of P_2 as required. The constant of proportionality found experimentally is 0.95 instead of unity which, considering the idealized model used in the construction of the theory and the probable differences in adsorption between the linen paper used in these tests and the cotton employed by Urquhart and Williams, is a sufficiently close check.

Of particular importance is the direct evaluation of $\frac{2\lambda}{R}$ which Fig. 1 makes possible. This value of 200 millimeters

mercury has independent significance as the quantity by which the pressure within the pores of the paper exceeds the external pressure. Furthermore, the direct substitution of $\lambda = 32.7$ dynes/cm., the surface tension of the chlorinated naphthalene used in these experiments at the temperature at which the samples were prepared gives the effective pore radius.

$$R = 2.46 \times 10^{-4} \text{ cms.} = 2.46 \text{ microns.}$$

It should be stated that about 5 per cent. of the 200 mm. can be accounted for by the hydrostatic head of impregnant covering the samples.

APPLICATION.

The general theory presented has been found useful in explaining qualitatively, and in some cases quantitatively as in the above case, certain phenomena observed in work on impregnated paper. It has found practical use in solving problems concerning preparation of laboratory samples, determination of moisture in impregnated paper and the drying and impregnation of paper for electrical uses. These applications are briefly outlined below:

1. Preparation of Laboratory Samples

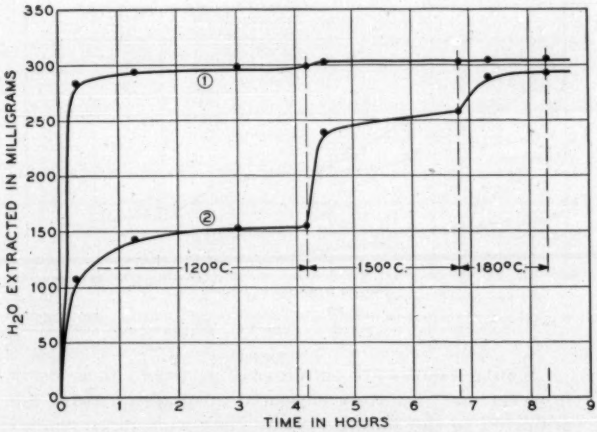
For those concerned with the electrical properties of paper, it is often convenient to have a means of preparing samples of impregnated paper of uniform moisture content. This can be done by the method described in the first section of this paper and used in the previously reported work. One can use Fig. 1 directly for this purpose, taking account, however, of the differences in surface tension among different impregnants. For preparation of samples at other temperatures, one need only take into account the change in the vapor pressure-moisture content relation of the paper and the change in surface tension of the impregnant. When it is more convenient to vary the temperature and to evacuate to zero pressure, a close approximation to the desired moisture content can still be obtained provided the surface tension of the impregnant and the desorption isotherms of the paper are known approximately. It is

necessary to adjust the temperature so that $\frac{2\lambda}{R}$ is equivalent to the pressure on the desorption isotherm corresponding to the desired moisture content.

2. Determination of Moisture

The theory and results described above disclose an obstacle in the path of determination of moisture in impregnated paper by direct distillation. Figure 2 illus-

FIG. 2.

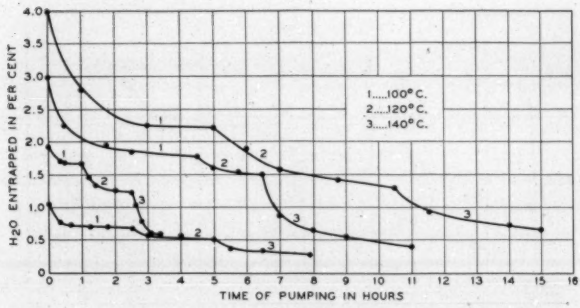


Extraction of water from paper, 10 gm. samples. (1) No impregnant present. (2) Immersed in Aroclor 1254 (chlorinated diphenyl). Samples evacuated during test to < 1.0 mm. Hg.

trates the nature of the difficulty encountered. Curve 1 is for an unimpregnated 10-gram sample of paper containing initially about 300 milligrams of water. It is seen that upon evacuation, virtually all of the moisture present is obtained by evacuation for two to three hours while the sample is held at 120° C. For the sample represented by Curve 2, however, quite a different result is found. This is also a 10-gram sample of about

the same moisture content but immersed in Aroclor (chlorinated diphenyl) during the moisture determination. Evacuation for four hours at 120° C. fails to remove much more than half of the moisture originally present. Even after an additional evacuation for two and one-half hours with the temperature increased to 150° C., about one-half per cent. of water remains entrapped. Only by going to 180° C. does the moisture evolved begin to approach the true moisture content of the sample.

FIG. 3.



Effect of initial moisture content on entrapping of moisture in paper. Initial moisture contents of 3.99 per cent., 2.98 per cent., 1.93 per cent., and 1.05 per cent.

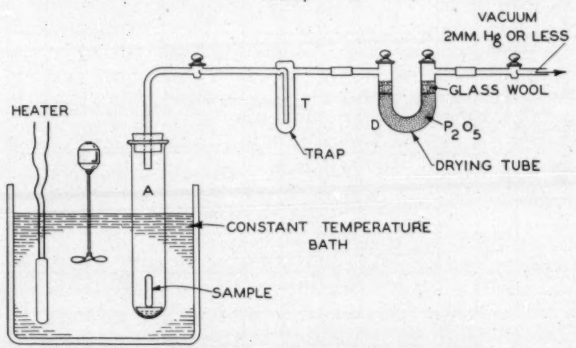
Similar results are shown in Fig. 3. In these tests, however, an accurately measured quantity of water was admitted to the samples before they were impregnated. The advantage of this procedure in testing the efficiency of moisture extraction is that the amount of water present at the start of the experiment is accurately known.

These results would, of course, be predicted from the preceding discussion. The higher the temperature the higher the vapor pressue of the water from the sample and hence the less remains entrapped. A second factor of minor importance operating in the same direction is the decrease in surface tension of the impregnant

as the temperature is increased, a factor which has a proportional effect upon the magnitude of $\frac{2\lambda}{R}$.

In the above experiments, the samples were completely immersed in impregnant during the moisture extraction. This is the most unfavorable condition for complete extraction of moisture. In the determination of moisture in impregnated paper, considerable is gained by having as little excess impregnant present as possible. For the purposes of moisture determinations in our laboratory, the apparatus shown in Fig. 4 is used. After excess impregnant is removed from

FIG. 4.



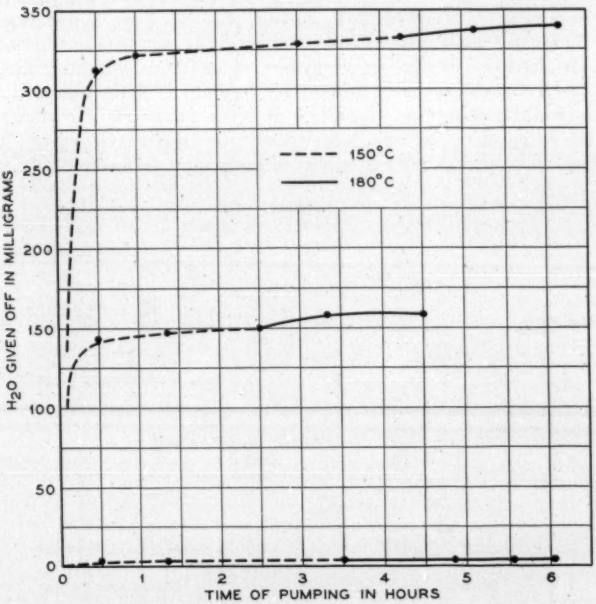
Apparatus used for moisture determination in impregnated paper.

the sample, it is supported in the sample tube so that any excess impregnant can drip into the bottom of the tube. The sample is allowed to come to the bath temperature before evacuation is begun, at which temperature the wax impregnants are completely molten. When evacuation is begun, the sudden rush of water plus dissolved and adsorbed gases purges the sample of additional impregnant.

The advantage in moisture determinations of these conditions over those used in the former experiments is seen

by comparing Fig. 5 with Figs. 2 and 3. Actually, the same efficiency of moisture extraction is obtained at temperatures 20 to 30 degrees lower.

Fig. 5.



Determination of moisture in 3 samples of impregnated paper by method outlined in text.

The temperature which it is necessary to use in determining moisture by direct distillation depends upon many factors such as the nature and form of sample and the accuracy required. In most work in our laboratory, evacuation at a temperature of 150° C. for four hours is sufficient if the above precautions are taken. This procedure gives a fair accuracy which varies slightly with initial moisture content and a precision of ± 0.02 per cent. on 10-gram samples.

3. Drying of Paper

The difficulty of drying paper in the presence of impregnant is readily explained by the theory of trapping due to surface tension forces. Since it is not possible to reduce the effective pressure within the pores of paper below $\frac{2\lambda}{R}$, one must depend entirely upon the extremely slow diffusion process for elimination of moisture below that given by the adsorption isotherm at the pressure $\frac{2\lambda}{R}$.

The following general principle appears to be sound: A truly dry impregnated paper can be obtained within reasonable time only if the paper is thoroughly dry at the time it is brought into contact with the impregnant.

4. Impregnation of Paper

In the impregnation of paper for electrical uses, it is essential that entrapped gases be eliminated as far as possible. This is due to the fact that the dielectric strength of gases is less than that of the impregnated structure. Furthermore, if the impregnated paper is to serve as a condenser dielectric, the obtaining of the highest capacities depends upon the elimination of entrapped air and other gases.

If the theory presented in this paper is correct and of general application, it appears that impregnants would be capable of exerting significant entrapping effects upon gases as well as upon moisture. The effects would be less on a weight per cent. basis due to the small adsorption of gases by paper.

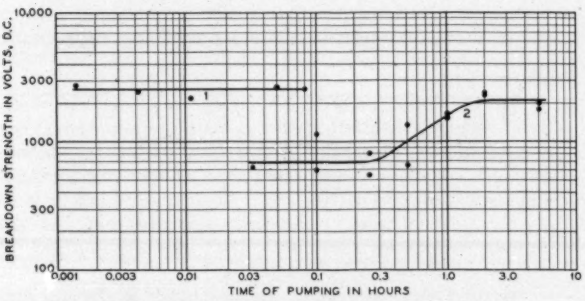
However, it is readily demonstrated that impregnants of low vapor pressure do exert significant entrapping effects upon gases in paper. For purposes of exposition, let us consider two possible ways of obtaining gas-free impregnated paper. It will be assumed that the principle laid down in the previous section is observed and hence that the paper is dry before an attempt is made to impregnate it. Method 1—the paper is evacuated and held at a low pressure while impregnant is admitted to cover the sample, after which the whole is let down to

atmospheric pressure. Method 2—the dry paper is immersed in impregnant at atmospheric pressure and the whole mass of paper plus impregnant evacuated.

The theory presented in this paper would predict that by Method 2 difficulty would be encountered owing to the entrapping of gases in the porous spaces of the paper by the $\frac{2\lambda}{R}$ surface tension forces.

That this is true is readily demonstrated. Figure 6 shows d-c. breakdown voltage measurements on 0.0008″

FIG. 6.



Influence of entrapped gases on the dielectric strength of impregnated paper. Curves 1 and 2 correspond to methods 1 and 2 of impregnation. Dielectric thickness 0.0008 inches.

impregnated paper samples prepared by the two methods. The results are plotted as breakdown voltage versus time of evacuation. By using method 1, good breakdown strengths are obtained with the very shortest evacuation times used (5 seconds) while by method 2, two hours evacuation is required to obtain reasonably good breakdown voltages.

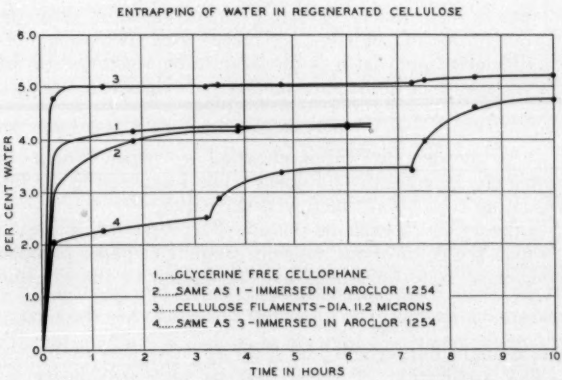
Before ending this section, it should be pointed out that effective impregnation and good breakdown strengths can be obtained by method 2 more readily if the completed material need not be free of moisture. If one starts with paper containing considerable moisture, the water vapor evolved quickly sweeps out the residual

gases. When the atmospheric pressure is admitted the water vapor is readsorbed by the paper creating a partial vacuum which draws the impregnant into the pores. Such an impregnated paper would naturally not make a good electrical insulating material because of its high residual moisture content. The same result may be accomplished, however, by using a volatile organic liquid such as benzene thereby making it possible to oven dry the sample and impregnate without the use of pumps.

5. Bearing on Porous Structure

Studies of the removal of water from paper immersed in impregnating compounds definitely show that the porous structure of paper cannot be regarded as consisting of capillary tubes in which water condenses to an extent dependent upon the vapor pressure, and which

FIG. 7.


ENTRAPPING OF WATER IN REGENERATED CELLULOSE
PER CENT WATER
TIME IN HOURS
1.....GLYCERINE FREE CELLOPHANE
2.....SAME AS 1 - IMMERSED IN AROCLOR 1254
3.....CELLULOSE FILAMENTS - DIA. 11.2 MICRONS
4.....SAME AS 3 - IMMERSED IN AROCLOR 1254

Extraction of moisture from impregnated cellulosic materials of various physical structures.

can then be completely filled by impregnation with an organic liquid. Caclulations of pore size by means of the Kelvin equation show that the molecular dimensions of the common impregnating compounds will not permit

these molecules to enter the pores in which water condenses in the low humidity range. These calculations are confirmed by experiments on sheets of glycerine free cellophane, the results of which are shown in Fig. 7. Curves 1 and 2 of this figure show that water absorbed by cellophane may be completely removed by pumping underneath the impregnating compound, suggesting that the surface tension forces which must be overcome by the water vapor pressure are those which act between or around fibers and that the water is held on surfaces or in pores within the fiber which are not accessible to the impregnating compound.

To obtain confirmation of this, experiments were carried out on regenerated cellulose in the form of filaments 11 microns in diameter, the results of which are shown by curves 3 and 4 of Fig. 7. The entrapping of water is again found, supporting the conclusion that interfiber spaces are involved in this effect. Experiments with fibers of larger diameter show that the magnitude of the effect decreases with increasing fiber diameter, but that it is too large to be accounted for by the sheath of liquid surrounding the cylindrical filament.

SUMMARY.

It is shown that water adsorbed by paper cannot be completely removed by pumping while immersed in an impregnating compound which wets the paper.

A theory which explains this effect is presented, according to which the equilibrium moisture content of paper pumped under these conditions does not correspond to the external pressure but to one $\frac{2\lambda}{R}$ greater than this where λ is the surface tension of the impregnant and R the effective pore radius.

The application of these findings and the theory to the preparation of experimental samples of impregnated paper of controlled moisture content; to the determination of moisture in impregnated paper; to the drying and impregnation of paper and to the investigation of the pore structure of solids is discussed.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

NEW UNITS OF ELECTRICITY AND LIGHT.

The introduction of absolute units in electricity and the new system of units of light, which was to have taken place on January 1, 1940, in accordance with decisions of the International Committee on Weights and Measures, must now await resumption of normal international relations. Although the new methods of defining the units will be fundamentally different from the old, the actual size of the units will not be changed enough to affect seriously present commercial usage in the United States. It would be possible to make the change independently, but one of the principal purposes of the proposed change is to obtain and to maintain closer agreement between the units used in different countries; this purpose would be defeated by separate action of one country.

Early in 1939 it became evident that final agreement upon values for the units could not be reached soon enough to permit their use at the beginning of 1940. (See *Technical News Bulletin* 265; May, 1939.) In particular, the German national laboratory, the Physikalisch-Technische Reichsanstalt, had not completed its absolute measurements of electric current, and some German authorities had questioned the validity of the spectral luminosity factors which had previously been accepted as the basis for photometry of lights differing in color from the primary standard (a black body at the temperature of freezing platinum). It was hoped, however, that these difficulties might be resolved to such an extent that the General Conference on Weights and Measures, meeting in October, could at least set a new date for adoption of the new units.

At meetings of the International Advisory Committee on Photometry and of the International Commission on Illumination, held in June, unanimous agreement was reached to re-

* Communicated by the Director.

tain the accepted luminosity factors and to complete the system of practical photometric standards derived from the platinum black body by means of those factors. International comparisons of gas-filled incandescent standard lamps were to be made, so that the new units could be introduced for all types of lamps in all countries on January 1, 1941.

On the electrical units no such definite recommendation could be made, because the German measurements of current were not finished and preliminary results were not concordant with those obtained in other countries. Arrangements were made for direct comparisons of apparatus between the Reichsanstalt and the National Bureau of Standards in order to find the cause of the discrepancies in results.

The war has, of course, prevented the execution of these plans. The meetings of the International Committee and the General Conference on Weights and Measures scheduled for October were cancelled and no progress toward international agreement on the units can be made until peace is restored. In the meantime the Bureau is continuing experiments to confirm or correct its own determinations of the electrical units. In photometry, the results of international comparisons so far as they were completed were satisfactory.

INDUSTRIAL USES FOR SILVER.

The American Silver Producers' Research Project issued its Tenth Progress Report November 1, 1939. This report reviews the progress made since release of the Ninth Progress Report dated July 1, 1939, and reviewed in *Technical News Bulletin* 268 (August, 1939).

During the past half year several companies have been following up the work of the Project on the lining of cans with vaporized films of silver. Studies are being continued at the Bureau to evaluate the merit of various types of can linings as a foundation upon which a silver film may be deposited. Some can linings have been produced with very thin films of silver which have a mirror-like appearance and resist peeling when in contact with certain beverages. As the value of the silver used in such linings is only a small fraction of a cent per can, this phase of the work has aroused considerable commercial interest.

The study of electroplated silver coatings has been continued, and good deposits of silver have been made at 240 amperes per square foot current density. The rate of deposition of silver in some experiments was forty times the normal rate. These high-current densities are possible under conditions involving a turbulent flow of the electrolyte. In order to silver-plate containers, for example, using automatic machinery, it appears necessary to use methods requiring high rates of silver deposition.

The possibility of electroforming complicated shapes, such as distilling flasks, has been demonstrated, and several silver flasks have been produced by the method of electroforming.

A study has been made of the embrittlement of steel as a result of cleaning and plating operations.

The metallurgical program has included the preparation and study of alloys of silver with small amounts of the following metals: Arsenic, antimony, aluminum, nagnesium, manganese, nickel, silicon, and zinc. The properties of bronzes and of lead and tin containing small amounts of silver have been determined. The Tenth Progress Report presents data relating to these metallurgical studies.

A comprehensive study is being made of the effect of silver in amounts up to 0.15 per cent. upon the properties and performance of antimonial lead storage batteries.

All of the above work is being undertaken at the Bureau. In addition, work is continuing at Rensselaer Polytechnic Institute, Cornell University, and Lehigh University. The Rensselaer Polytechnic Institute data are being accumulated so that silver graphite brushes can be compared in performance with conventional brush materials. At Cornell University attention has been focused on obtaining a fungicidal silver spray of suitable adhesiveness. The toxicity of silver for fungous organisms has been demonstrated by the use of silver sulphate in a mildew preventive paint. Similarly, antifouling paints containing silver salts have shown some promise.

At Lehigh University, the resistance of silver to various industrial corrosives is being compared with the corrosion resistance of metals now used industrially. Data have been accumulated dealing with the corrosion resistance of silver to sulfuric acid, hydrochloric acid, phenol, acetic acid, sodium

hydroxide, phosphoric acid, hydrofluoric acid, and acid mine water. Much of this work has been carried on at the suggestion of companies facing a particular corrosion problem. Additional suggestions of this nature will be welcomed.

A book, entitled, "Argyria—The Pharmacology of Silver," by Doctors Pillsbury and Hill has been published recently by Williams and Wilkins Company, and presents the results of the silver research fellowship at the University of Pennsylvania relating to this subject.

In view of the fact that the Project is scheduled to terminate at the end of next May, work has commenced on the preparation of a book which will include the results obtained by the various research fellows connected with the Project during the course of their investigations. It is also planned to include other useful data regarding silver and its alloys. It is expected that the publication will issue in the fall of 1940.

STRUCTURAL PROPERTIES OF "BENDER STEEL HOME" WALL CONSTRUCTION.

Tests have been made at the Bureau on 21 specimens of sheet-steel wall constructions sold under the trade name "Bender Steel Home," and submitted by the Bender Body Company.

This wall construction consists of sheet-steel studs and outside face, with fiber insulating board inside face, and additional fiberboard insulation between the two. The steel, according to the Sponsor's statement, is a nickel-copper alloy. Rivets and bolts are of the same material, and bolts are cadmium plated. Floors are sheet steel panels, but partitions, roofs, and ceilings are of conventional wood-frame type.

As described in Building Materials and Structures Report BMS27, copies of which are now obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each, four-and eight-foot wall specimens were subjected to compressive, transverse, concentrated, impact, and racking loads. The transverse, concentrated, and impact loads were applied to both faces of the specimens to simulate the actual loads applied to the walls of a house.

For each of the loads three like specimens were tested.

The deformation under load and the set after its removal were measured for uniform increments of load, except for concentrated loads, for which the set only was determined. The results are presented in graphs and in a table.

EFFECT OF BRONZE ON MARBLE.

A series of exposure tests has been started to determine if bronze work mounted above marble may affect the durability of the marble. It has long been known that bronze will cause green or brown discolorations on marble but some cases have indicated that there is a more serious effect. Green stains are evidently caused by the copper component of the bronze but the cause of disintegration is not known.

Experiments are in progress on three compositions of bronze, as follows:

(1) 90 parts copper, 8 parts tin, 2 parts lead;
(2) 88 parts copper, 10 parts tin, 2 parts zinc;
(3) 80 parts copper, 3 parts tin, 16 parts zinc, 1 part lead.

The bronzes were cast in the form of round bars and turned on a lathe in order to produce shavings which were used in the tests so that a large area of bronze would be exposed to rain water. Containers made out of sheet bronze in the form of boxes, open at top and bottom, were placed upon white calcite marble specimens 4 × 1½ × 24 in. in size. The containers holding 1800 grams of bronze shavings were attached at the middle of each marble specimen. Fifteen specimens were made for each type of bronze and fifteen more were exposed in a similar manner without bronze in contact, for control purposes. Since the composition of the bronze boxes was somewhat different from the bronze samples, a few tests were added in which only the boxes were attached to the marble slabs. These were used to determine if the small amount of bronze in the boxes would cause any appreciable differences.

The specimens have now been exposed to the weather for 18 months and the following observations have been made:

The turnings from Bronze No. 1 have changed somewhat in color from the original golden shade to a depth of about ¼

inch, while underneath this layer there has been no appreciable change.

The turnings from Bronze No. 2 have become gray, resembling zinc, to a depth from ½ inch to 1 inch.

Those for Bronze No. 3 became gray like No. 2 to a depth of about ½ inch.

Brown stains have formed on the top surfaces of the marble slabs, extending about ½ inch away from the boxes. These were pronounced for Bronzes 1 and 2, but less so for Bronze 3. Green stains have formed only on the edges of the marble and they are very faint. A few slabs which had been treated with a sealer show no brown stains, but green stains on the edges are as marked as on those not treated.

INFRA-RED ARC SPECTRUM OF GERMANIUM.

The element germanium shares with gallium and scandium the distinction of having its existence foretold and its properties described prior to its actual discovery. In 1871 Mendeléeff announced his periodic classification of the chemical elements and predicted three new members to occupy the gaps in the table as it then existed. The final verification of his predictions occurred in 1886 when Winkler discovered a new element, germanium, with the properties ascribed by Mendeléeff to eka-silicon. The element is rare and only small amounts have been prepared in a pure state.

For theoretical reasons it is known that a portion of the arc spectrum of germanium must lie in the infra-red. The more intense lines in this region have now been recorded on the specially sensitized plates of the Eastman series with the grating spectrographs of the Bureau. C. C. Kiess has classified most of the new lines as combinations between the previously known $^3P^\circ$ and $^1P^\circ$ terms of the $5s$ configuartion with new triplet and singlet terms of the $5p$ configuration. The yellow lines observed by Lunt in spark and discharge tube sources are found to be lines of Ge I and, in analogy with similar lines of C I and Si I, probably owe their origin to the $5s-6p$ transition.

The complete account of this work will be published as RP1266 in the *Journal of Research* for January.

COMMERCIAL STANDARD FOR AUTOMATIC MECHANICAL DRAFT OIL BURNERS.

Commercial Standard CS75–39 "Automatic Mechanical Draft Oil Burners Designed for Domestic Installations" has just been released.

This standard is intended to serve as a basis for better understanding between buyers and sellers. It includes specific requirements for oil burner construction, safety, manufacturing and production tests, laboratory performance tests, and performance requirements and tests to be made by the contractor after installation of the individual burner. Also, it describes the wording of a certificate which is to be posted in the basement along with each oil burner installation, setting forth the manufacturer's warranty; data applying to the particular installation, such as the amount of standing radiation; the results of tests by the installing contractor, recording the grade of fuel oil used, the draft over the fire and at the breeching, the percentage of CO_2 in the flue gases, the stack temperature, and the firing rate.

The pamphlet also includes a section on the significance of installation requirements and performance tests, for the benefit of those who may not be familiar with the subject.

It is expected that a wide use of the certificate and the seal of the official inspection agency of the oil burner industry, evidencing compliance with the commercial standard, will result in a distinct improvement in the quality and performance of mechanical draft oil burners, while purchasers will be provided with a definite basis for checking and comparing their performance.

The standard became effective for new production on November 1, 1939. Copies are for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.

Air Conditioned Blast Furnace.—(*Heating and Ventilating*, Vol. 36, No. 12.) The first air conditioned blast furnace is now successfully operating at the plant of the Woodward Iron Company at Woodward, 12 miles southwest of Birmingham. The 535 ton installation was made at an estimated cost of $75,000. The primary object of the installation is to control the moisture content, summer and winter, of the air blast required in blast furnace operation to the end that a more uniform product can be produced. The value of having a dry blast in the process has long been recognized, but the Woodward Company was the first to turn to modern air conditioning to attain this objective. The capacity of the furnaces at Woodward is 400 to 550 tons of iron per day, and the air required is from 45,000 to 50,000 c.f.m. or about 2700 tons of air per day. Thus for every ton of iron produced, 5.6 tons of air must be conditioned. In smelting, the principal functions of the furnace are to dry the charge, release the calcium from the carbonates, reduce the metallic oxides in the ore, and to melt the iron. To accomplish these objectives, air is blown into the furnace where the combustion of the coke results in a temperature of around 3000° F. Carbon dioxide is formed but immediately broken down into carbon monoxide which is a powerful reducing agent. While President Berg of the company has made public no figures as to the performance of the equipment, decision to proceed with the second furnace is taken as evidence that the installation has proved satisfactory in its major purpose of affording a more uniform product through scientific control of heat, moisture and air blast.

R. H. O.

THE FRANKLIN INSTITUTE.

ANNUAL MEETING, JANUARY 17, 1940.

The Annual Meeting of The Franklin Institute was held on the evening of Wednesday, January 17, 1940, at 8:15 o'clock with Dr. Henry Butler Allen, Secretary and Director, in the Chair.

The minutes of the previous meeting were approved as published in the January issue of the JOURNAL.

The report of the Tellers of the annual election was read and the following gentlemen were declared elected to the respective offices:

President (To serve 1 year)	Philip C. Staples
Vice-Presidents (To serve 1 year)	Walton Forstall
	W. Chattin Wetherill
	S. S. Fels
	Richard W. Lloyd
Treasurer (To serve 1 year)	Benjamin Franklin
Managers (To serve 3 years)	Irenee DuPont
	W. H. Fulweiler
	Nathan Hayward
	Horace P. Liversidge
	Malcolm Lloyd, Jr.
	Marshall S. Morgan
	Coleman Sellers, 3rd
	William H. Winterrowd

The additions to membership since the last report were as follows:

Active	10
Associate	16
Student	50
Total	76

The Chairman also presented the Annual Report of the Board of Managers on the activities of the Institute during the year 1939.

After the transaction of this business the meeting became a joint one with the Physics Club and Physics Colloquium of Philadelphia. Dr. G. P. Harnwell, President of the Physics Club, was invited to act as Chairman of the meeting. After the transaction of a few items of business of the Club, Dr. Harnwell introduced Dr. Enrico Fermi, Professor of Physics at Columbia University, New York City, who addressed the meeting on "Nuclear Bombardment with Neutrons."

The speaker described his many experiments and investigations in this field and referred especially to nuclear bombardments for producing atomic disintegra-

tions; transmutations of elements and nuclear chemistry; fast and slow neutrons. He also discussed the different types of transmutations produced by neutrons. Reference was also made to the fission of uranium and of the heaviest elements of the periodic system. The speaker accompanied his remarks with blackboard illustrations.

At the conclusion of the address there was a spirited discussion of the subject. A rising vote of thanks was tendered the speaker.

Adjourned,

HENRY BUTLER ALLEN,
Secretary.

UNVEILING OF TABLET HONORS ELIHU THOMSON.

Dr. Elihu Thomson, who died in 1937, was a long time member of The Franklin Institute and in the early days of his career was an instructor in the schools of this old society.

Because of his close association with the Institute, it was glad to sponsor the erection of a tablet by his early Lynn Associates to commemorate his work in making the first bi-phase dynamo.

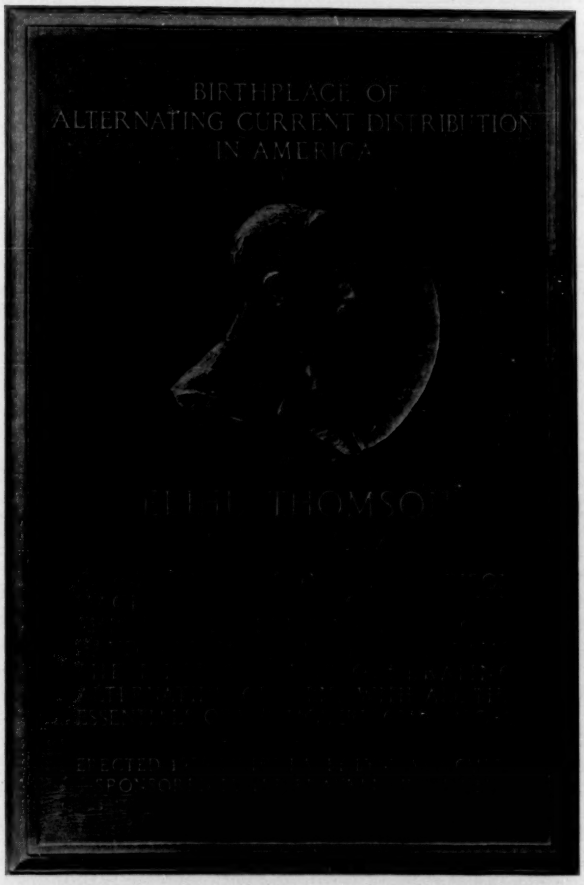
Marked by very simple exercises, the tablet was unveiled at noon on Wednesday, January third, by Mrs. Elihu Thomson. It was erected on the Middle City Building, Ludlow Street, Philadelphia.

Dr. Henry Butler Allen, Secretary and Director of The Franklin Institute, spoke briefly of Dr. Thomson's connection with the Institute and referred to the many pieces of equipment and apparatus which form the Elihu Thomson Exhibit in the Institute's museum.

Dr. John L. Haney, President of the Central High School, also gave a short address, recalling to mind Dr. Thomson's activities at the high school, where he had served as an instructor for many years.

Representing the Elihu Thomson Associates, Mr. A. L. Rohrer, of Maplewood, New Jersey, one of the men associated with Dr. Thomson in his early electrical work, told of that work and of the reason for the erection of the tablet. His remarks follow:

Elihu Thomson possessed a many-sided mind—Chemistry, Physics, Mechanics, Astronomy, Medicine, Electricity, he enriched them all.


BIRTHPLACE OF
ALTERNATING CURRENT DISTRIBUTION
IN AMERICA

One of Professor Thomson's greatest contributions was to the important problem of the distribution of alternating current energy, and his was the earliest here in America. He saw that it was possible to produce a system of alternating current distribution which was automatically self-regulating by the simple expedient of putting the primaries of the transformers in multiple across the generator mains, and putting the energy-consuming devices in multiple across the mains connected to the secondaries of the transformers.

This thought, which is the foundation of the whole modern art of generation, transmission and distribution of electric energy, was worked out by Professor Thomson here in Philadelphia in the years 1878 and 1879, sixty years ago.

But, Professor Thomson, throughout his whole life, took very seriously the responsibility of providing for the safety of the public. He realized the possibility that the insulation of the transformers might break down in such a way as to put the high-tension voltage directly onto the secondary mains. This would result in all sorts of dangers, including the danger of fire, and the greater danger of fatal shock from the high tension current. He was therefore unwilling to put out his system commercially, in spite of its extraordinary merit, until he could see some way of surely and definitely protecting the customer from the dangers just described. He did not accomplish this until he invented several safety devices, the principal one being the grounding of the secondary, the patent for which he dedicated to the public. In the after-years Professor Thomson received a handsome set of resolutions from the Western Society of Electrical Inspectors, which called him "The Father of Safety Grounding."

So this danger was minimized, and indeed practically eliminated, and Professor Thomson was then willing to put the system into commercial use.

Professor Thomson was always primarily interested in the fundamentals. I remember that during the years 1884 and 1885 he would on occasion speak of the possible use of induction coils in a lighting system. Then, beginning early in 1886, with more time at his disposal, and with increased laboratory facilities, he devoted himself to some special experimental work. He built a number of pieces of apparatus and a long

series of experiments were undertaken, the results of which he included in a paper which he read before the American Institute of Electrical Engineers early in 1887, under the title "Novel Phenomena of Alternating Current," demonstrated with apparatus in which he made evident to his contemporaries the many great possibilities of his system. The effect of his disclosures at that time can hardly be over-estimated. They furnished inspiration to many inventors and scientists whose names later were associated with the design and manufacture of alternating current apparatus.

One of the most striking of the many original experiments which Professor Thomson made at that time, and one which attracted great attention at the Paris Exposition in 1889, was the so-called repulsion experiment; he found that a short-circuited secondary, for example a ring of copper, placed over the pole of an alternating current magnet, was repelled by that pole. This discovery led him to many important inventions, one of which was sustained as the fundamental patent on the induction motor.

This same experiment was later repeated several times in England, when it created even greater interest.

During a period of years—beginning about 1860, and including 1878 and 1879—there stood on this site, then Barker Street, a jobbing shop known as the Harrison Machine Works. The proprietor was William H. Harrison, a machinist, and he allowed Professor Thomson to use the tool equipment for such work as he wanted to do in putting into practice his ideas about electric apparatus.

Professor Thomson had great facility of hand and wrist; he could equal the work of a high grade mechanician. He made wood patterns, got the castings, did all the machine work and, of course, the winding of the armature and fields; when the parts were assembled he called it a Bi-Phase Dynamo. Later such machines were called "Alternators."

Meanwhile, Professor Thomson had constructed a pair of induction coils, and as incandescent lamps did not then exist, he also made a pair of vibrating arc lamps. Near the end of 1878 all this apparatus was ready for the initial test. By an arrangement of belts and counter-shafting used ordinarily to drive the machine tools the bi-phase dynamo was driven, and

we must draw on our imagination as to the various schemes and devices his fertile brain resorted to in order to obtain results or values.

This dynamo, which seems tiny today, with the other pieces of apparatus have been preserved and are now in the Franklin Institute Museum, all connected up in the same manner as Professor Thomson had them in the Harrison Machine Works in 1878.

In 1879 the outfit was moved to the lecture hall of The Franklin Institute Building, then located on Seventh Street, which had a small steam engine used for testing purposes and allowed a more extended series of tests to be made in the months of January and February. So that site should share the honor of this day.

Because of the original work done here on this site and elsewhere by Professor Thomson, together with the later work of two generations of scientists and inventors, the alternating current field has reached enormous proportions. Today, with the exception of a few thousand K.W. of direct current at Niagara Falls, used for chemical work, a few thousand in Cleveland and in Detroit where the energy is largely a by-product, no Central Station in America generates for transmission and sale a single K.W. hour of Direct Current; it is all alternating current.

The generating capacity in hydraulic plants has reached an output as great as 82,000 K.V.A. and in steam turbine plants they have gone as great as 200,000 K.V.A.

Here on this site was born what has become a mighty giant. The claim is justified that this is the birthplace of alternating current distribution in America.

Philadelphia should be proud that her schools educated Elihu Thomson; that The Franklin Institute gave him facilities for his experiments and tests; that the American Philosophical Society encouraged him. Then, in 1880 Philadelphia gave him to the World. He became an international figure.

Of all who were associated with Professor Thomson in the design and installation of the early commercial alternating current apparatus, only four survive—J. R. Lovejoy, H. G. Reist, W. J. Foster, and myself. Doctor Allen has been pleased to designate us as The Elihu Thomson Associates.

We have long had a strong desire to mark suitably this site, which is historic in the evolution of the electric industry.

We thank you for joining us today in honoring the memory of a distinguished scientist, a great inventor, and an ideal gentleman—Professor Elihu Thomson.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday January 10, 1940.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JANUARY 10, 1940.

MR. WILLIAM G. ELLIS *in the Chair.*

The following reports were presented for final action:

No. 3065: Glass Filaments, Improved Method and Apparatus for Making Same.

This report recommended the award of an Edward Longstreth Medal to Games Slayter, of Newark, Ohio, "In consideration of his achievement in devising improved methods and apparatus for making spun and blown glass filaments."

No. 3073 } The Standing Sub-Committee on the Franklin Medal recom-
No. 3074 } mended that a Franklin Medal be awarded in 1940 to:

LEO HENDRIK BAEKELAND, of New York City, New York, "In recognition of his inventions and his contributions to the improvement of the industrial arts, and, in particular, of his invention and manufacture of the synthetic product, Bakelite";

And one to:

ARTHUR HOLLY COMPTON, of Chicago, Illinois, "In recognition of his brilliant experiments on various properties of X-rays, some of which involved new methods of attack, and, in particular, for his discovery and theoretical treatment of the Compton Effect."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The committee on Library desires to add to the collections of the Institute any technical writings of members who have had occasion to publish such material.

Literary contributions from author-members will be gratefully acknowledged, properly inscribed and noted in the Journal of the Institute.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print $8\frac{1}{2} \times 11$ inches is forty cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays two until ten o'clock P.M. 723 readers made use of the facilities during the twenty-five days of December.

RECENT ADDITIONS.

AERONAUTICS.

CHAMBLISS, W. C., AND W. F. MCDONALD. Private Pilot's Handbook. 1939.

AGRICULTURE.

BENNETT, HUGH HAMMOND. Soil Conservation. 1939.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

CUMMING, ALEX. CHARLES, AND SYDNEY ALEXANDER KAY. Text-book of Quantitative Chemical Analysis. Seventh Edition. Revised by F. C. Guthrie and J. T. Nance. 1939.

LANGE, NORBERT ADOLPH. Handbook of Chemistry. Third Edition, Revised and Enlarged. 1939.

PAULING, LINUS. The Nature of the Chemical Bond and the Structure of Molecules and Crystals. 1939.

ELECTRICITY AND ELECTRICAL ENGINEERING.

American Radio Relay League. The Radio Amateur's Handbook. 1940. Seventeenth Edition. 1939.

MORGAN, HOWARD K. Aircraft Radio and Electrical Equipment. 1939.

Radio Handbook. Sixth Edition. 1939.

ENGINEERING.

American Society for Testing Materials. 1939 Book of A. S. T. M. Standards Including Tentative Standards. Part 3: Nonmetallic Materials—General. 1939.

GEOLOGY.

FENNEMAN, NEVIN M. Physiography of the Eastern United States. First Edition. 1938.

FURNAS, C. C. The Storehouse of Civilization. 1939.

LOBECK, A. K. Geomorphology. First Edition. 1939.

INDUSTRIAL MANAGEMENT.

KIMBALL, DEXTER S., AND DEXTER S. KIMBALL, JR. Principles of Industrial Organization. Fifth Edition. 1939.

MANUFACTURES.

ADAM, HUGH M., AND JAMES H. EVANS. Metalwork. Third Edition. 1939.

GRAUMONT, RAOUL, AND JOHN HENSEL. Encyclopedia of Knots and Fancy Rope Work. 1939.

METALLURGY.

CHALMERS, BRUCE. The Physical Examination of Metals. Volume 1. 1939.

MINING ENGINEERING.

GAUDIN, A. M. Principles of Mineral Dressing. First Edition. 1939.

NAVAL ARCHITECTURE AND NAVIGATION.

VANDERBILT, HAROLD S. On the Wind's Highway. 1939.

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HENNEY, KEITH, AND BEVERLY DUDLEY. Handbook of Photography. 1939.
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NOTES FROM THE BARTOL RESEARCH FOUNDATION.

AN IMPROVED RADIOBAROGRAPH.*

BY

T. H. JOHNSON AND S. A. KORFF.

In the study of cosmic rays in the stratosphere, the technique of sending up small instruments in free balloons with an automatically keyed radio transmitter for sending back the data to a recording instrument in the laboratory is proving itself an invaluable method for obtaining all kinds of information. An essential element in all flights of this nature is a reliable and simple barograph for indicating the height of the balloon at each instant. The instrument described in the paper bearing the above title operates by the Olland-Curtiss principle, but is free from some of the more common defects of previous instruments. The instrument measures barometric pressure to within one millimeter over the entire atmosphere, it measures the temperature to one degree centigrade, and it keys dots and dashes on a radio transmitter whose relative spacings indicate the measurements.

GEIGER-COUNTER MEASUREMENTS IN THE UPPER ATMOSPHERE BEARING UPON THE NATURE OF THE RADIATION FROM SOLAR FLARES AND RADIO FADE-OUTS.†

BY

T. H. JOHNSON AND S. A. KORFF.

The intensity of the penetrating radiation at an elevation of 20 km. has been measured with a Geiger counter carried at a constant level by a balloon for a continuous interval includ-

* An abstract of a paper published in full in *Review of Scientific Instruments*, 10, 82 (1939).

† An abstract of a paper published in full in *Terrestrial Magnetism and Electricity*, 44, 21 (1939).

ing times before, during, and after a radio fade-out. No effect was found, and the precision of the measurement excludes the possibility of an increase of intensity as great as two per cent. Assuming mass-absorption of the ionizing radiation in a homogeneous atmosphere the limits of the absorption-coefficient are determined from (*a*) the negative result of the balloon experiment, (*b*) the total ionization required in the region of high collision-frequency for the absorption of radio energy, and (*c*) the fact that the *E*- and *F*-layers are not appreciably altered as regards their ion-density during the fade-out. The analysis shows that the mass absorption-coefficient must lie between 0.1 and 25 per gram, or if the solar-flare radiation is of the nature of X-rays the wave-length must lie between 0.1 and 1.5Å.

NEUTRON MEASUREMENTS WITH BORON-TRIFLUORIDE COUNTERS.*

BY

S. A. KORFF AND W. E. DANFORTH.

We have been studying the behavior of boron-trifluoride counters for use in the measurement of slow neutron intensities. Copper cylinders, ranging from seven to 40 cm. in length and one to seven cm. in diameter, have been used in glass envelopes with three-mil tungsten central wires. Before filling, they were washed with dilute nitric acid and heated with a flame during evacuation. Pressures of BF_3 from two to 20 cm. have been tried. Operating voltages were lowered and behavior improved by the addition of about one cm. of argon in each case.

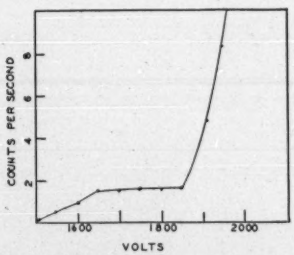
We define the threshold of a counter as that voltage at which it will break down into a continuous discharge if no quenching resistance is used. Below this threshold voltage, the ions formed in the tube are swept by the field to the central wire without starting a self-perpetuating discharge. The average number of ions so swept will be proportional to the number produced in the counter by the passage of the

* Reprinted from *The Physical Review*, **55**, 980 (1939).

ionizing ray. As the ions travel toward the wire, they produce additional ions by collision, and the number of additional ions will be a function of the voltage. In most counters, such as those filled with argon or air, there is a small voltage range, generally less than five volts below the threshold, within which pulses greater than 0.01 volt are produced on the wire. The boron-trifluoride counters have the property of producing large pulses over a considerably greater voltage range.

A slow neutron entering a counter filled with boron trifluoride produces an alpha-particle by disintegration of the boron nucleus. This alpha-particle will produce a large amount of ionization in the counter, as compared to that produced by cosmic-ray particles or gamma-ray secondaries. By setting the recording amplifier to record only the larger pulses, it is possible to count the alpha-particles to the exclusion of beta- or gamma-counts.

FIG. 1.



Counting rate near a beryllium source as voltage applied to the counter is increased.

The alpha-particle pulses produced by such counters can be as large as several tenths of a volt when the counter is operated at some 200 volts below the point where gamma-ray pulses of similar size are produced. No high quenching resistance is needed. The counter wire may be connected directly to the grid of the tube and a grid resistor of the order of one megohm is satisfactory.

In Fig. 1 is presented the counting rate of such a counter as a function of the applied voltage, when a radium-beryllium

neutron source was nearby. As the voltage applied to the counter increases, the average pulse size increases. The counting rate of the recorder, therefore, rises with voltage until even the smallest pulse produced by the alpha-rays is large enough to record. Further increase of voltage results in no change in the counting rate until that voltage is reached at which the largest of the gamma-ray pulses becomes large enough to operate the recorder. The threshold of this particular counter (11 cm. pressure, cylinder 20 cm. long, 1.8 cm. diameter) was 2080 volts.

The limiting neutron intensity which may be measured is that which is small compared to the natural background due to alpha-rays arising from contamination of the cylinder of the counter.

The efficiency of the counters was calculated from the boron cross section to be about 0.3 per cent. for the counters filled to 11 cm. pressure. The order of magnitude of this figure was verified experimentally by comparing the counting rate of a BF_3 counter with that arising from induced radioactivity in a silver (argon-filled) counter.

These counters have been used for about six months, in measuring the neutron intensity in the cosmic radiation in the stratosphere, as well as that due to sources in the laboratory. Stratosphere flights using automatic radio transmission of data with these counters indicate an increase of the neutron counting rate with elevation which is more rapid than the increase in the total radiation. At an elevation of three meters of water equivalent below the top of the atmosphere, the neutron intensity in the cosmic radiation is of the order of 100 times the sea level neutron intensity.

The work on these counters has been partly supported by the Carnegie Institution of Washington. The authors are indebted to M. D. Whitaker of New York University for the loan of the neutron source, and to W. F. G. Swann, T. H. Johnson, C. G. Montgomery and R. D. Fowler for helpful advice and assistance.

RECENT ADVANCES IN THE INVESTIGATION OF COSMIC RAYS.

BY

THOMAS H. JOHNSON.*

The paper bearing the above title is the printed edition of the Ninth Annual Joseph Henry Lecture of the Philosophical Society of Washington, delivered on March 25, 1939. After a brief historical account of the discovery of the cosmic radiation and of the experiments which proved the corpuscular nature of the primary rays, the paper reviews the methods which have been used and the results achieved in the analysis of the energy spectrum of the primary rays incident upon the top of the atmosphere, and of the total radiation found at sea level. In both instances, magnetic analysis proves the existence of rays of energies up to 5×10^{10} volts; absorption measurements carry the analysis up to more than 10^{11} volts; and the measurements of large bursts and showers, covering areas of more than 400 square meters, show the existence of cosmic rays of energies up to 10^{15} volts. The paper then considers the question of the nature of the particles which compose the cosmic radiation. Incident upon the top of the atmosphere are protons and both positive and negative electrons. The electron component accounts for most of the intensity at high elevations, but the protons make their effects felt at greater depths and are primarily responsible for practically all of the intensity at sea level and below. The radiation reaches these depths, however, by an indirect process in which the primary proton creates in the upper levels of the atmosphere one or more particles of intermediate mass and of both positive and negative charge, called mesons. These particles are too light to experience strong nuclear absorption, and too heavy to lose heavily by radiative collisions. Their energy is dissipated only by the more gradual process of ionization and in consequence they are able to penetrate further than either the electrons or the protons. A third method of energy loss makes its appearance, however, in the case of the meson, namely, radioactive decay, whereby

* An abstract of a paper published in full in the *Journal of the Washington Academy of Sciences*, **29**, 233 (1939).

the meson spontaneously vanishes and an electron and a neutrino take its place.

Finally the paper considers the electrical state of intergalactic space and shows that the primary proton component can be accounted for by the acceleration of positive ions, originally at rest, in the electric field set up by the charges on a cosmic ray source which emits electrons of high energy.

THE INTENSITY OF NEUTRONS OF THERMAL ENERGY IN THE ATMOSPHERE AT SEA LEVEL.*

BY

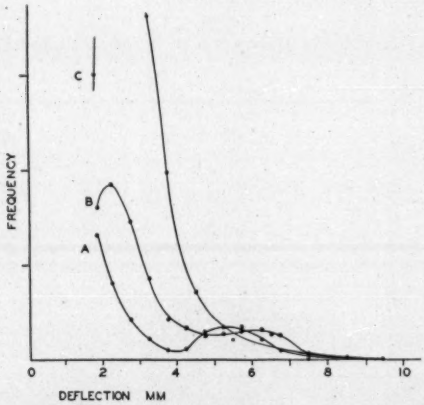
C. G. MONTGOMERY AND D. D. MONTGOMERY.

Neutrons were detected by utilizing the alpha-particles released in the disintegration of the boron isotope of mass ten. An ionization chamber in the form of a vertical cylinder of copper 40 cm. long and 7 cm. in diameter was enclosed in a glass envelope and filled with boron trifluoride gas at atmospheric pressure. The collecting electrode was a fine wire through the center of the cylinder. A dry battery supplied a steady potential of 450 volts to collect the ions formed. The collecting electrode was directly connected to the grid of an FP54 Pliotron. The voltage pulse from the FP54 resulting from a spurt of ionization caused by an alpha-particle was then applied to a type 38 vacuum tube for additional amplification, and the output of this tube was capacitatively coupled to a galvanometer. The position of the galvanometer spot was continuously recorded on moving photographic paper, and the alpha-particles appeared as kicks whose heights were proportional to the amounts of ionization produced by the alpha-particles. The natural alpha-particle background of the chamber caused by radioactive impurities was determined by shielding the chamber with a thick layer of borax which absorbed all neutrons of thermal energy falling upon it. The size-frequency distribution of the alpha-particle pulses so determined is shown in curve *A*, Fig. 1. When the borax shield was removed a larger number of alpha-particles was

* Condensed from a paper published in full in the *Physical Review*, **56**, 10 (1939).

observed, the increase being the number of alpha-particles resulting from the disintegration of the boron nuclei. The size-frequency distribution without the shield is shown in curve *B*, Fig. 1. As an additional check, some observations were made with a radium-beryllium source of neutrons. A 200-milligram source was placed in another room of the laboratory at a distance of about 15 meters, and shielded with about four inches of lead. The alpha-particle distribution in the ionization chamber in the presence of this source is given as curve *C* in Fig. 1.

FIG. 1.



Size-frequency distributions of the alpha-particles in the ionization chamber. Curve *A*—thick borax shield; curve *B*—no shield; curve *C*—200-milligram, Ra-Be neutron source 15 meters from apparatus.

The neutron flux may be expressed, with an error of less than five per cent., as $n/N\sigma V$, where N is the number of B^{10} atoms per cubic centimeter, V the volume of the chamber, and n the number of disintegrations observed and σ the reaction cross section. It is necessary to correct for the absorption (about 25 per cent.) by the boron in the glass envelope of the chamber. Using this expression, we find that the neutron flux, that is, the number of neutrons passing through a sphere of one square centimeter cross-sectional area in unit time is

0.091 ± 0.007 cm.$^{-2}$ min.$^{-1}$ if we assume the neutrons to have thermal energies. The flux of ionizing cosmic-ray particles is 1.48 cm.$^{-2}$ min.$^{-1}$, so that we have one neutron of thermal energy for every 16 cosmic rays.

The most probable process for the absorption of thermal neutrons will be the $N^{14}(n - p)C^{14}$ reaction. The cross section for this reaction [5] is 11.3×10^{-24} cm.^{2}, which corresponds to an absorption coefficient of 4.8×10^{-4} cm.$^{-1}$ of standard air. Now since equilibrium exists, as many neutrons must be formed as disappear, and we must have 4.4×10^{-5} neutron of thermal energy produced per cubic centimeter per minute. If no other process is important for neutron absorption, then this figure must also represent the total production of neutrons of all energies. If we assume that all atoms in the air interact with all the ionizing cosmic rays, we may compute the cross section for the production of a neutron to be 5.5×10^{-25} cm^2. This cross section is surprisingly high, and indeed, since other absorption processes may be important, and since all cosmic rays probably do not produce neutrons, this cross section must represent only a lower limit to that of the true process. It seems likely that the neutrons are produced by high energy photons, since they seem to be associated at sea level with showers, and increase with elevation as do the large bursts of ionization. It is interesting to note in this connection that the nuclear disintegrations observed by Anderson and Neddermeyer in cloud chambers increase with elevation in the same way, and quite probably give neutrons as disintegration products as well as the heavily ionizing particles which are observed.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

A Cell Adapted for Conductivity Measurements of Protein Solutions.—THOMAS J. DIETZ. (Physico-Chemical Department of the Biochemical Research Foundation of the Franklin Institute, Philadelphia, Pa.) Extensive electrophoretic studies usually require substantial amounts of serum; consequently when an electrophoresis apparatus is used in analysis of human serum it becomes desirable to reduce the volume requirement as much as satisfactory results will permit. Since conductivity measurements are useful for determining the potential gradient in the solution being analyzed, a conductivity cell of small volume is particularly desirable. The ionic concentration of undiluted or satisfactorily diluted serum is relatively high, so that a comparatively large conductivity cell has been required in standard procedures.

The standard forms of conductivity cell, in general, require large volumes of material, and also the arrangement of the cell elements is such as to make measurements of protein solutions troublesome. This is true because the electrodes of the cell usually stand out within the envelope so that bubbles are likely to be caught behind the electrodes, making cleaning and filling of the cell difficult. Various types of conductivity cells have been studied by Jones and Bollinger (*Journ. Am. Chem. Soc.*, **53**: 411, 1931) in order to determine desirable characteristics for cell design. Shedlovsky (*Journ. Am. Chem. Soc.*, **54**: 1411, 1932), following the specifications of Jones and Bollinger, devised a conductivity cell which required only small volumes. The Shedlovsky cell obviates the criticism made against earlier types and has been found to be satisfactory for use in electrophoresis studies by Longsworth, Shedlovsky and MacInnes (*Journ. Exptl. Med.*, **70**: 399, 1939).

A micro-conductivity cell requiring a volume of fluid of only 0.45 cc. was devised by Fink and Gross (*Mikrochemie*, **18**: 169, 1936). However, the error of a single measurement

was about 0.2 per cent. and the reproducibility, 0.3 per cent. The errors inherent in this type of cell are considered to be higher than desirable for electrophoretic work. Furthermore this cell is practically useless for measurements on solutions of high protein content, because of the tendency to trap bubbles. In this laboratory a simpler type of conductivity cell was desired for electrophoretic studies on limited specimens of human and animal sera. For such a cell of low constant to give satisfactory service under conditions imposed, that is, conductivity measurements on salt solutions between 0.1 N and 0.02 N potassium chloride, it is necessary to limit the cell characteristics required for more general use.

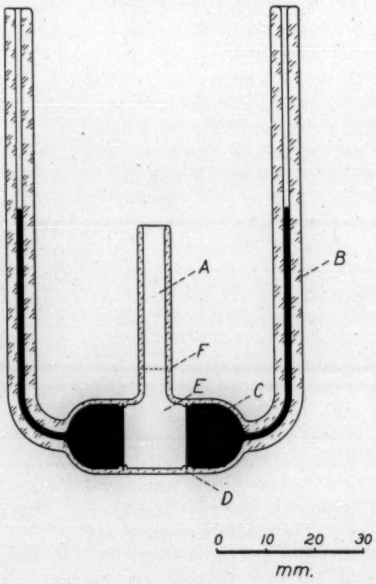
A cell was devised in which the possibility of trapping air behind the electrodes was eliminated by sealing disc-shaped electrodes directly into the glass envelope. It was desirable to use lead glass as the cell envelope to make a satisfactory seal to the platinum electrodes. The space behind the electrode was extended with a capillary tube and filled with mercury for contact terminal. One of the usual filling arms was omitted and a single short arm, centrally placed and properly stoppered, served for washing and filling the cell. No difficulty has been encountered by the elimination of the second arm; the cell can be regularly washed and filled with the aid of a hypodermic syringe and large sized needle from which the point has been ground. The terminal arms are conveniently longer than the filling arm so that the cell can be inverted in a shallow dish of mercury in a vacuum desiccator to facilitate filling the mercury chambers. This conductivity cell is shown in the accompanying drawing.

The usual procedure for determining the errors inherent in a conductivity cell is to measure the conductivities of several concentrations of a salt whose specific conductivity is known, and to make these measurements at three or more different frequencies, say, one thousand, two thousand and three thousand cycles. In a cell which is properly designed the cell constant should be independent of frequency. In the cell here illustrated, measurements of cell constant were made at frequencies of one thousand, two thousand and three thousand cycles, on solutions of potassium chloride of concentrations from 0.1 N to 0.02 N. The variation of cell constant with

frequency was less than 0.2 per cent., and the probable error of a single measurement was 0.024 per cent.

The most important error in measurements with conductivity cells is due to polarization at the electrodes. Polariza-

FIG. 1.



Conductivity cell for protein solutions—*A*, filling arm; *B*, electrode arm; *C*, mercury contact; *D*, sealed-in platinum electrode; *E*, space for solution to be measured; and *F*, reference mark for constant volume.

tion effects can be reduced by increasing the area of the electrodes, by increasing the inter-electrode distance, by raising the cell constant, or by increasing the frequency of the power supplying the measuring circuit. Obviously the first three of these features are objectionable if small volume is to be retained. Besides, any attempt to reduce polarization effects

by greatly increasing the frequency induces parallel leakages with subsequent error in measurement. Therefore in the design of a conductivity cell of small volume concessions must be made on one or more of these points.

The Cyclotron of the Biochemical Research Foundation.—A. J. ALLEN, M. B. SAMPSON AND R. G. FRANKLIN. (JOURNAL OF THE FRANKLIN INSTITUTE, **228**: 543, 1939.) Certain features of the Biochemical Research Foundation cyclotron, which may be of interest to those building a similar machine, are presented: (1) The design and construction of the magnetic circuit, (2) results of a survey of the magnetic field with and without "shimming," (3) the construction and dimensions of the vacuum tank and deflector, (4) the design of dee supports with a convenient arrangement for the adjustment of the dees, (5) modified ion sources using tungsten ribbon filaments, one of which enables the cyclotron to deliver a current of at least 30 microamperes of deuterons at 11 Mev. on an external target, (6) a high frequency system for supplying voltage to the dees.

Attempts to Detect a Reaction Between Human Allergic Serum and Its Antigen.—JOHN M. NEWELL. (*Journal of Allergy*, 11: 35, 1939.) Does the human sufferer from hay fever or asthma have an antibody in his blood which will react in the test tube with the material that causes the trouble? In the lower animals it is common to find antibodies which precipitate the substance to which the animal is sensitive. However, workers in the field of human allergy have not been able to find such antibodies and it is generally believed that the beneficial results of injections are due to reactions which take place in the living cells and not in the fluids of the blood.

This question was examined to see whether newly developed methods of studying proteins could detect any reactions between human allergic serum and the substance to which the donor of the serum was sensitive.

In the first experiment the serum of a person sensitive to rabbit hair and to rabbit serum was examined by means of the air-driven ultracentrifuge. This human serum, as do the sera of most adults, contained antitoxin to staphylococcus

toxin. A mixture of the human serum and dilute rabbit hair extract (0.0001 milligram of protein nitrogen per cubic centimeter) was centrifuged at 100,000 times gravity for three hours. Samples were then pipetted off the top, middle, and bottom of the centrifuge cup and tested for the presence of rabbit hair extract by skin test. The extract was found in all samples, showing that it had been thrown down little, if any, by the centrifuging. The antibody could not be detected directly but the antitoxin to staphylococcus, which is the same sort of protein, was found in the samples from the middle and bottom only. Thus it would appear that antitoxin can be thrown down by the ultracentrifuge leaving behind the substance to which the allergic person is sensitive. In other words, this experiment showed no evidence of a physical union between the antigen and antibody.

Experiments with the same purpose were carried out using the Tiselius electrophoresis apparatus. Antibody from the same human serum was freed from the albumin present in the serum by means of electrophoresis. The human antibody was then mixed with albumin prepared from rabbit serum. The components of this mixture migrate at different rates when an electric current is passed through the solution. The migration can be followed in the Tiselius apparatus by observing the refraction of a light beam passing through the mixture. No new boundaries were found so that there was no evidence of a new compound being formed by the human antibody and the rabbit albumin. Skin tests showed the rabbit albumin to be strong in the faster migrating portion and weak in the slower portion while serological tests showed just the opposite distribution for the human antibody.

In a second test, a scale was photographed through the apparatus as the electrophoresis was being carried on. Measurement of the amount by which the lines of the scale were displaced permitted an estimation of the differences in concentration of the components of the mixture. Whole serum from the same person as in the previous experiments was mixed with albumin from rabbit serum. Plotting of the displacement of the lines resulted in curves with peaks for albumin and three globulins: alpha, beta, and gamma. No significant difference could be found between the curves from

human serum alone or mixed with rabbit albumin except that the peak for albumin was increased by the amount of the rabbit albumin. Antibodies have been found to be associated with the gamma globulin fractions. This latter was practically the same in both cases. Thus again there is no evidence of a physical union between antigen and antibody.

These negative findings support the belief that in human allergy the reaction between the antibody and its antigen does not take place in the fluids of the blood.

BOOK REVIEWS.

THE PHOTOGRAPHIC PROCESS, by Julian Ellis Mack and Miles J. Martin. 586 pages, illustrations, 19 × 25 cms. New York, McGraw-Hill Book Company, Inc., 1939. Price $5.00.

Few sciences have had the phenomenal growth in recent years as photography and again few have become as generally popular. But even today not many professionals or amateurs realize the great diversity of uses to which photography is applied. In this respect as in the outlook for further development, there seems to be no end in sight. The literature in this field, because of its rapid growth, is woefully lacking in textbooks on principles, compared with other fields of applied science, and is mainly restricted to elementary instruction books and a few special treatises. It is therefore gratifying to see the contribution of "The Photographic Process."

This book was written primarily for use as a text in a course in photography at the University of Wisconsin. Examination of it reveals that its content and arrangement is such that it is suited also to the requirements of photographers having only as much as high school attainments and who desire to have an understanding of the photographic process sufficient to make the practice of photography an intelligent application of principles rather than a blind following of rules of thumb. To facilitate the use of the book for these two applications, part of it is printed in a large type which gives the easier and basic treatments, and a smaller type is used to indicate the more advanced information.

After an introduction which briefly sets forth the requirements of the photographic process and which outlines the history of photography, the work starts with the subject of photographic optics. This includes a short but comprehensive explanation of polarized light and a more extensive description of perspective. This leads to the achievements of a pin hole camera and the subject of lenses. Cameras and accessories are next taken up followed by the aspects of image perpetuation including structure of the medium in which the image is perpetuated, light transmitting properties of the finished negative, development and auxiliary processes, influence of color on the recorded image and positive prints including projection prints. The remaining parts of the book are devoted to natural color photography where a broader understanding of the nature of color is given, scientific and technological photography such as in astronomy and photomicrography, photochemical reproduction, and pictorial photography.

The book is well composed. The subject matter proceeds from the simple to the more complex and is of the character containing an abundance of interesting matter with the technical data. There are numerous problems where necessary for exercise as in the conventional text. A bibliography provides references for further study if desired. Also there are appended a manual of experiments for use in coordinating the experimentation as closely as possible with the study of the theory, and a formulary for the experiments. This book can be recommended to students and photographers alike.

R. H. OPPERMANN.

A TEXT BOOK ON LIGHT, by A. W. Barton. 426 pages, plates, illustrations, 15 × 23 cms. New York, Longmans, Green and Co. Price $3.00.

Here is a textbook which has an underlying theory of presentation quite unusual. Its aim is to train the student to be better able to do original work and to solve problems in practice, and this is accomplished by attempting to trace the growth of the ideas correlating the experimental evidence and the modification of those ideas by the further investigations which they have suggested. As an illustration, when a set of facts which were known at a certain date have been discussed and established, the theories which were put forward to correlate them are expounded solely in the light of those facts. In this way an uncertainty is created by evolving a dispute between theories and interest thus arousing results in progression of study to a more modern viewpoint and so on until the whole story up to the present knowledge is covered. To evaluate this method would require a study of the book with this in mind alone and perhaps considerable experience in its use, but certainly there are, at the outset, some very definite points in its favor.

There are seventeen chapters to the book beginning with geometrical optics and proceeding through the design of optical instruments and their practical application. The theory of the various lens aberrations is developed and it is shown that this has helped the lens designer in producing the best possible lens for a given purpose. Further, Newton's work on the nature of white light was inspired by the desire to improve telescopic images and to eliminate the coloring at the edges which led ultimately not only to the solution of that problem but also to the discovery of spectra bidding fair to revolutionize the very basis of physical science.

Later, attention is given the question "What is light?" The treatment illustrates how the corpuscular theory seemed to correct the answer at first on account of its simple explanation of rectilinear propagation, but that it was slowly displaced by the wave theory because it could correlate a wider range of facts. The phenomena of interference and diffraction, not rectilinear propagation, turned out to be the facts giving the key as to the nature of light. Conclusion is made with an account of the photo-electric effect and Compton effect, which demand a revival of the corpuscular theory in a new form.

The work is very much to the point, stopping short of abruptness. It relies on the interest in and sufficient prerequisites for the study to carry its aims to a successful conclusion. In these situations it surely has points, but for application to large numbers of students with the possibility of at least a sizeable portion varying in these qualities, the results can only be estimated by those in the teaching profession. The coverage of the book, however, is complete and the viewpoints well taken in keeping with the limitations outlined.

R. H. OPPERMANN.

EXCURSIONS IN SCIENCE, by Neil B. Reynolds and Ellis L. Manning. 307 pages. New York, McGraw-Hill Book Company, Inc. Price $2.50.

In May 1936 the General Electric Company instituted a radio program, called the Science Forum, designed to present the meaning, scope, and several purposes of modern scientific research and engineering in language that could be understood by the intelligent layman. As part of the program, workers in many fields of science were invited to present short talks on their particular fields of study.

This book is the result of the gathering together a group of these talks and editing them so that they are more in the proper form for reading. The point is stressed that in no case has the editing been accomplished so as to distort or change in any way the original meaning of the author.

There are thirty-six papers in all on as many subjects. Each one is complete in itself—in other words an excursion, just as the title of the book implies—and the reader need not read any of the others in order to understand one. To give an idea of the diversity of subjects covered the following is an example: The Nature of Lightning by Dr. Karl B. McEachron; Vacuum by E. F. Hennelly; Science and Superstition by N. B. Reynolds; How Your Radio Tubes Work by E. D. McArthur; Electron Optics by Dr. R. P. Johnson; Ozone by Dr. F. J. Norton. A feature of the book is the inclusion of a brief biographical sketch of the author at the beginning of each paper. The papers are interestingly written emphasizing the personality of the author with regard to what he thinks are points of most importance in his work. In the back there is an index useful for reference purposes.

One of the things the book should definitely establish in the mind of the layman is the practical value of what has been termed "pure" research which has been considered generally as having academic value only.

R. H. OPPERMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 664, Wind-Tunnel Investigation of an N. A. C. A. 23012 Airfoil with Various Arrangements of Slotted Flaps, by Carl J. Wenzinger and Thomas A. Harris. 31 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 15 cents.

An investigation was made in the 7- by 10-foot wind tunnel and in the variable-density wind tunnel of the N. A. C. A. 23012 airfoil with various slotted-flap arrangements. The purpose of the investigation in the 7- by 10-foot wind tunnel was to determine the airfoil section aerodynamic characteristics as affected by flap shape, slot shape, and flap location. The flap position for maximum lift; polars for arrangements considered favorable for take-off and climb; and complete lift, drag, and pitching-moment characteristics for selected optimum arrangements were determined. The best arrangement was tested in the variable-density tunnel at an effective Reynolds Number of 8,000,000. In addition, data from both wind tunnels are included for plain, split, external-airfoil, and Fowler flaps for purposes of comparison.

The optimum arrangement of the slotted flap was superior to the plain, the split, and the external-airfoil types of flap on the basis of maximum lift coefficient, low drag at moderate and high lift coefficients, and high drag at high lift coefficients. The increment of maximum lift due to the slotted flap was found to be practically independent of the Reynolds Number over the range investigated. The slotted flap, however, gave slightly lower maximum lift coefficients than the Fowler flap. It was found that slot openings in the airfoil surface at the flap caused a measurable increase in drag of the airfoil for the condition of high-speed flight even if the slot was smoothly sealed on the upper surface and there was no flow through the slot. It was also found that, in order to obtain the highest lift coefficients, the nose of the flap should be located slightly ahead of and below a slot lip that directs the air downward over the flap.

Report No. 665, Calculation of the Aerodynamic Characteristics of Tapered Wings with Partial-Span Flaps, by Henry A. Pearson and Raymond F. Anderson. 18 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

Factors derived from wing theory are presented. By means of these factors, the angle of zero lift, the lift-curve slope, the pitching moment, the aerodynamic-center position, and the induced drag of tapered wings with partial-span flaps may be calculated. The factors are given for wings of aspect ratios 6 and 10, of taper ratios from 0.25 to 1.00, and with flaps of various lengths.

An example is presented of the method of application of the factors. Fair agreement with experimental results is shown for two wings of different taper ratio having plain flaps of various spans.

Report No. 668, Wind-Tunnel Investigation of N. A. C. A. 23012, 23021, and 23030 Airfoils with Various Sizes of Split Flap, by Carl J. Wenzinger and Thomas A. Harris. 13 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

An investigation has been made in the N. A. C. A. 7- by 10-foot wind tunnel of large-chord N. A. C. A. 23012, 23021, and 23030 airfoils with split flaps 10, 20, 30, and 40 per cent. of the wing chord to determine the section aerodynamic characteristics of the airfoils as affected by airfoil thickness, flap chord, and flap deflection. The complete section aerodynamic characteristics of all the combinations tested are given in the form of graphs of lift, drag, and pitching-moment coefficients, and certain applications to aerodynamic design are discussed.

The final maximum lift coefficients for the three airfoils tested with the 0.20 c_w flap were about equal. For the airfoils with the 0.10 c_w flap, the maximum lift coefficient decreased with airfoil thickness; for the airfoils with the 0.30 c_w or 0.40 c_w flaps, the maximum lift coefficient increased with airfoil thickness to a maximum value of 2.94. Within the range covered, the increment of maximum lift coefficient due to the split flaps was practically independent of Reynolds Number. The increase in minimum profile-drag coefficient with airfoil thickness was large, being about twice as great for the N. A. C. A. 23030 as for the 23012 plain airfoil.

Report No. 669, Airfoil Section Data Obtained in the N. A. C. A. Variable-Density Tunnel as Affected by Support Interference and Other Corrections, by Eastman N. Jacobs and Ira H. Abbott. 32 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

The results of an investigation of the effect of support interference on airfoil drag data obtained in the variable-density tunnel are presented. As a result of the support interference, previously published airfoil data from the variable-density tunnel have shown too large drag coefficients and too large a rate of increase of drag coefficient with airfoil thickness. The practical effect of the corrections on the choice of the optimum section is briefly considered and corrected data for a selected list of airfoils are presented as a convenience to the designer. Methods of correcting published data for other airfoils are presented.

Report No. 672, Free-Spinning Wind-Tunnel Tests of a Low-Wing Monoplane with Systematic Changes in Wings and Tails. IV. Effect of Center-of-Gravity Location, by Oscar Seidman and A. I. Neihouse. 20 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

Eight wings and three tails, covering a wide range of aerodynamic characteristics, were independently ballasted so as to be interchangeable with no change in mass distribution. For each of the 24 resulting wing-tail combinations, observations were made of the steady spin for four control settings and of recoveries for five control manipulations. The results are presented in the form of charts comparing the spin characteristics. The tests are part of a general investigation being made in the N. A. C. A. free-spinning tunnel to determine the effects of systematic changes in wing and tail arrangement upon the steady-spin and the recovery characteristics of a conventional low-wing monoplane for various load distributions.

The present tests are a continuation of the investigation, the entire series of tests performed for the basic loading being repeated with the center of gravity 10 per cent. forward and 10 per cent. back of the normal location at 25 per cent. of the mean chord. The results are compared with those for the basic loading condition.

For all tail and wing arrangements, there was a definite effect of center-of-gravity location, the forward location giving steeper spins and faster recoveries and the rearward location giving flatter spins and slower recoveries than the basic center-of-gravity location. The spin coefficient $\Omega b/2V$ increased as the center of gravity was moved forward and decreased as the center of gravity was moved back. In general, there was a tendency for the rate of descent to increase and for the sideslip to become more outward as the center of gravity was moved forward.

Report No. 673, Experimental Verification of the Theory of Oscillating Airfoils, by Abe Silverstein and Upshur T. Joyner. 5 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

Measurements have been made of the lift on an airfoil in pitching oscillation with a continuous-recording, instantaneous-force balance. The experimental values for the phase difference between the angle of attack and the lift are shown to be in close agreement with the theory.

Report No. 676, Surface Heat-Transfer Coefficients of Finned Cylinders, by Herman H. Ellerbrock, Jr., and Arnold Biermann. 14 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

An investigation to determine and correlate the experimental surface heat-transfer coefficients of finned cylinders with different air-stream cooling arrangements was conducted at the Langley Memorial Aeronautical Laboratory from 1932 to 1938. The investigation covered the determination of the effect of fin width, fin space, fin thickness, and cylinder diameter on the heat transfer. Wind-tunnel tests were made in the free air stream with and without baffles and also with various devices for creating a turbulent air stream. Tests were also made with blower cooling.

A variation of the initial turbulence of the tunnel air stream was found to have little effect on the heat transfer. Correlation of the surface heat-transfer coefficients was found possible by plotting a factor involving the heat-transfer coefficients, the fin space, and the conductivity of the cooling air against a factor involving the velocity, the density, and the viscosity of the cooling air and the fin space, the fin width, and the cylinder diameter.

Report No. 677, Wind-Tunnel Investigation of an N. A. C. A. 23021 Airfoil with Various Arrangements of Slotted Flaps, by Carl J. Wenzinger and Thomas A. Harris. 24 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

An investigation has been made in the N. A. C. A. 7- by 10-foot wind tunnel of a large-chord N. A. C. A. 23021 airfoil with several arrangements of 25.66-per cent.-chord slotted flaps to determine the section aerodynamic characteristics as affected by slot shape, flap shape, flap location, and flap deflection. The flap positions for maximum lift, the polars for arrangements considered favorable for take-off and climb, and the complete section aerodynamic characteristics for selected optimum arrangements were determined. A discussion is given of the relative merits of the various arrangements for certain selected criterions. A comparison is made of a slotted flap on the N. A. C. A. 23021 airfoil with a corresponding slotted flap previously developed for the N. A. C. A. 23012 airfoil.

The best slotted-flap arrangement on the N. A. C. A. 23021 airfoil gave the same maximum lift coefficient as the best slotted flap on the N. A. C. A. 23012 airfoil. The drag coefficients were higher with the N. A. C. A. 23021 airfoil, but the pitching-moment coefficients were about equal for comparable arrangements.

Report No. 679, Wind-Tunnel Investigation of an N. A. C. A. 23012 Airfoil with a Slotted Flap and Three Types of Auxiliary Flap, by Carl J. Wenzinger and William E. Gauvain. 27 pages, illustrations, tables, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 15 cents.

An investigation was made in the N. A. C. A. 7- by 10-foot wind tunnel to determine the aerodynamic section characteristics of an N. A. C. A. 23012 airfoil with a single main slotted flap equipped successively with auxiliary flaps of the plain, split, and slotted types. A test installation was used in which an airfoil of 7-foot span was mounted vertically between the upper and the lower sides of the closed test section so that two-dimensional flow was approximated.

On the basis of maximum lift coefficient, low drag at moderate and high lift coefficients, and high drag at high lift coefficients, the optimum combination of the arrangement was found to be the double slotted flap. All the auxiliary flaps tested, however, increased the magnitudes of the pitching moments over those of the main slotted flap alone.

Report No. 680, The Effect of Nacelle-Propeller Diameter Ratio on Body Interference and on Propeller and Cooling Characteristics, by James G. McHugh and Eldridge H. Derring. 19 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

An investigation was conducted in the N. A. C. A. 20-foot tunnel to determine the slipstream drag, the body interference, and the cooling characteristics of

nacelle-propeller combinations with different ratios of nacelle diameter to propeller diameter. Four combinations of geometrically similar propellers and nacelles, mounted on standard wing supports, were tested with values of the ratio of nacelle diameter to propeller diameter of 0.25, 0.33, and 0.44.

The results show that (1) the effect of variation in the ratio of nacelle diameter to propeller diameter on propulsive efficiency is not important until the nacelle becomes approximately one-third of the propeller diameter but, beyond that point, the propulsive efficiency decreases rapidly with further increase in relative body size; (2) the net efficiency of a nacelle-propeller combination decreases rapidly with increasing values of the ratio of nacelle diameter to propeller diameter; (3) the presence of a spinner over the propeller hub increases the propulsive efficiency by an amount varying from 1½ to 4 per cent.; and (4) the maximum pressure drop available with adjustable cowling flaps is about 20 per cent. greater than the maximum pressure drop available with an adjustable-length cowling skirt.

QUALITATIVE ORGANIC CHEMISTRY, by Neil Campbell. 213 pages, illustrations, 14 × 21 cms. New York, D. Van Nostrand Company, Inc., 1939. Price $2.60.

The stated aim of this book is to present the principles of qualitative organic analysis and to give some idea of the methods used in examining organic compounds. To do this, the author has divided his book into two parts, part *A* outlining the methods used in qualitative work and part *B* containing a reference section with data for identification of some hundreds of organic compounds. The former first discusses how to determine the degree of purity of an unknown compound and then proceeds further by subjecting it to preliminary tests, supplementary tests, classification according to the functional groups present which includes derivatives suitable for the identification, and finally the last stage, the preparation of crystalline derivatives and determination of their melting points. A brief treatment is given on the examination of mixtures, considering separation only of mixtures with two components. The compounds isolated are purified and identified by the methods described in earlier chapters.

In part *B* of the book several hundreds of compounds are classified, each group being arranged in order of boiling points or melting points. A short summary of the properties of each compound is given together with the derivatives used for its identification.

Being essentially for elementary students, this book omits many tests and derivatives commonly included in textbooks. Care is taken in this matter which reflects keen insight not only from the teaching standpoint but from the economic as well. The book may be taken as a compact guide and may find practical laboratory use.

R. H. OPPERMANN.

RUTHERFORD, BEING THE LIFE AND LETTERS OF THE RT. HON. LORD RUTHERFORD, O.M., by A. S. Eve, with a foreword by Earl Baldwin of Bewdley. 451 pages, plates, illustrations, 17 × 26 cms. New York, The Macmillan Company, 1939. Price $5.00.

Every student of modern science is familiar with the greater achievements of Lord Rutherford. But just how great a man he really was, through his wonderful

personality as a man and in inspiration to others, as well as the large number of contributions to scientific thought and method, few can have an intimate acquaintance. The author of this book was formerly Professor of Physics at McGill University, worked as a colleague with Rutherford and has since had fullest access to private memoranda and correspondence. The facts set forth are therefore authoritative from the standpoint of their source and the personality pictured comes from observation and knowledge.

The presentation is one of exceptional merit, utilizing as much as possible original letters and other papers, these cleverly connected together to make a smooth flowing story in chronological order. No matter how complete the raw material of the author, a very exhaustive study must have been made to result in the many details here recorded. Expert composition has accomplished the rest, a book easy to read, instructive of the life of a great man.

It is not possible to summarize the scientific work of Rutherford recorded in the book. From playing with the nuclei of atoms, radioactivity was systematised, the nucleus discovered, and transmutation achieved. On the more human side, Rutherford loved children, he was a leader with young and old, and was very versatile. With his death a great epoch in science came to an end.

The book is a complete work, even to the subject index in the back and the list of honors accorded to Lord Rutherford, among which is the Franklin Medal 1924. Scientific workers will find here a book that they cannot afford to overlook for it provides a relaxation which is informative and valuable.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Fundamental Processes of Electrical Discharge in Gases, by Leonard B. Loeb. 717 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1939. Price $7.00.

Cosmic Rays, by R. A. Millikan. 134 pages, plates, illustrations, 14 × 21 cms. New York, The Macmillan Company, 1939. Price $2.50.

Mineral Metabolism, by Alfred T. Shohl. 384 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1939. Price $5.00.

Die Ultrazentrifuge, Theorie, Konstruktion und Ergebnisse, von Prof. Dr. The Svdberg und Dr. Kai O. Pedersen. 436 pages, illustrations, tables, 16 × 24 cms. Dresden, Theodor Steinkopff, 1940. Price 26.25 R.M.

Science for the World of Tomorrow, by Gerald Wendt. 316 pages, plates, illustrations, 14 × 21 cms. New York, W. W. Norton & Company, Inc.

Illinois Department of Registration and Education. Division of the State Water Survey Bulletin No. 32, Anaerobic Fermentations. 193 pages, illustrations, tables, 15 × 23 cms. Urbana, Illinois.

The Mechanical Inventions of Emanuel Swedenborg, translated and edited by Alfred Acton. 51 pages, illustrations, 15 × 23 cms. Philadelphia, Swedenborg Scientific Association, 1939. Price 60 cents.

Canada. Department of Trade and Commerce, Dominion Bureau of Statistics· Annual Report on the Mineral Production of Canada during the calendar year 1937. 333 pages, 17 × 25 cms. Ottawa, King's Printer, 1939. Price 50 cents.

Canada. Department of Mines and Resources, Mines and Geology Branch. The Canadian Mineral Industry in 1938. 102 pages, illustrations. The Mining Laws of Canada, A Digest of Dominion and Provincial Laws Affecting Mining, compiled by Arthur Buisson. 110 pages. 2 pamphlets, 17 × 25 cms. Ottawa, King's Printer, 1939. Price 25 cents each.

National Advisory Committee for Aeronautics. Technical Notes: No. 735, Pressure-Distribution Measurements on a Tapered Wing with a Partial-Span Flap in Curved Flight, by Th. Troller and F. Rokus. 12 pages, illustrations. No. 736, Tidewater and Weather-Exposure Tests on Metals Used in Aircraft, by Willard Mutchler and W. G. Galvin. 57 pages, illustrations. No. 737, Photoelastic Analysis of Three-Dimensional Stress Systems Using Scattered Light, by R. Weller and J. K. Bussey. 25 pages, illustrations. No. 738, Corrugated Metal Diaphragms for Aircraft Pressure-Measuring Instruments, by W. A. Wildhack and V. H. Goerke. 41 pages, illustrations. No. 739, A Recurrence Formula for Shear-Lag Problems, by Paul Kuhn. 29 pages, illustrations. No. 740, Stress Concentration around an Open Circular Hole in a Plate Subjected to Bending Normal to the Plane of the Plate, by C. Dumont. 28 pages, illustrations. No. 741, Observations in Flight of the Region of Stalled Flow over the Blades of an Autogiro Rotor, by F. J. Bailey, Jr., and F. B. Gustafson. 19 pages, illustrations. No. 742, Pressure-Distribution Measurements on a Rectangular Wing with a Partial-Span Split Flap in Curved Flight, by Frank G. Rokus. 14 pages, illustrations. No. 743, Local Instability of Columns with I-, Z-, Channel, and Rectangular-Tube Sections, by Elbridge Z. Stowell and Eugene E. Lundquist. 24 pages, illustrations. 8 pamphlets, 20 × 26 cms. Washington, Committee, 1939.

Bell Telephone System, Monographs: B-1166, Cold-Cathode Gas-Filled Tubes as Circuit Elements, by S. B. Ingram. 11 pages, illustrations. B-1170, Tarnish Studies, by W. E. Campbell and U. B. Thomas. 22 pages, illustrations. B-1171, Remaking Speech, by Homer Dudley. 23 pages, illustrations. B-1172, On Diffraction and Radiation of Electromagnetic Waves, by S. A. Schelkunoff. 21 pages, illustrations. B-1173, A General Radiation Formula, by S. A. Schelkunoff. 18 pages, illustrations. B-1174, Internal Electrolysis as a Method of Analysis, by Beverly L. Clarke and L. A. Wooten. 10 pages, illustrations. B-1175, A 50-Kilowatt Broadcast Station, by W. H. Doherty and O. W. Towner. 11 pages, illustrations. B-1176, Deviations of Short Radio Waves from the London-New York Great-Circle Path, by C. B. Feldman, 30 pages, illustrations. B-1177, Cation Exchange in Cellulosic Materials, by D. A. McLean and L. A. Wooten. 13 pages, illustrations. B-1178, An Electrochemical Study of the Corrosion of Painted Iron, by H. E. Haring and R. B. Gibney. 15 pages, illustrations. B-1179, Sol and Gel in Hevea Latex and Crude Rubber, by A. R. Kemp and H. Peters. 17 pages, illustrations. B-1181, Experience in Applying Carrier Telephone Systems to Toll Cables, by W. B. Bedell, G. B. Ransom and W. A. Stevens. 41 pages, illustrations. 12 pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1939.

CURRENT TOPICS.

Electroforming With Iron.—(*Chemical and Metallurgical Engineering*, Vol. 46, No. 10.) The Ekko process is a new method for the preparation of molds and dies which grew out of researches by the United States Rubber Co. on the production of cheaper tire molds. During the course of this development but before tire molds were an accomplished fact, it became obvious that this method offered advantages to almost all industries using molds and dies. The molds and dies produced effect a savings for the customer or permit him to produce more ornate and attractive articles hitherto prohibited by tool costs. The process produces molds and dies by electroforming iron against a pattern it is desired to reproduce. Electroforming is the same as electroplating except that deposits up to ½ in. thick are produced instead of the much thinner metal applied by the usual electroplating processes. When heavy electroformed deposits of iron are separated from the underlying pattern, a cavity or die insert is obtained which has reproduced the shape and surface finish of the pattern in every detail. This cavity or die when properly mounted may be used to mold or stamp objects the exact shape of the original pattern. Patterns upon which to deposit the iron need not be of rubber as in preparation of tire patterns. Provided the surface is made conducting, wood, glass, plastic or similar materials may be used; any metal is satisfactory with the exception of zinc and aluminum which are attacked by the plating bath.

R. H. O.

New Laboratory for Testing Motor Fuels and Lubricants Under Operating Conditions.—(*The Petroleum Engineer*, Vol. 11, No. 1.) The new automotive laboratory recently completed at the Point Breeze, Philadelphia, refinery of the Atlantic Refining Company provides a graphic illustration of the extent to which the petroleum industry is directing the facilities of scientific research to the constant testing and improvement of products used by the motoring public. Of concrete block construction, the new laboratory has a floor space approximately 10,000 sq. ft., and contains advanced equipment for testing motor fuels and lubricants under road and service conditions. Severe winter operating conditions can be simulated by means of a refrigeration and blower system that can supply cold, dehumidified

air at a velocity as high as 70 miles an hour to the chassis dynamometer test room, an adjacent cold room for engine tests, and a third cold room for small test equipment such as spring lubricant test machines, wheel bearing test machines, and other lubrication test devices. The temperature of each of these rooms can be varied from minus 20 to 120 deg. F. The refrigeration is supplied by two 50 hp. and one 15 hp. automatically controlled compressor units having a daily ice making capacity of 88 tons at an atmospheric temperature of 60 deg. F. The performance of fuels and lubricants in passenger cars and trucks can be tested under these widely varying temperatures and wind velocities, and under similarly widely varying degrees of load, in a chassis dynamometer test room.

R. H. O.

Soybean Oil Paints Stand Weather Exposure Tests.—Soybean oil paints and varnishes subjected to exposure tests at the United States Regional Soybean Laboratory, Urbana, Ill., are standing the test of time as well as paints and varnishes made from tung, perilla, and linseed oils report Department of Agriculture scientists. At present the soybean oil paints harden and dry somewhat more slowly than paints made from the other oils, but this apparently does not interfere with the durability of the soybean product. White exterior paints made from commonly used pigments together with soybean oil or half soybean oil and half perilla oil have been compared with similar paints made from linseed oil. After exposure for 2 years on outside fences, all of the panels are in excellent condition. New and cheaper varnishes made by blends of soybean oil, bakelite, and rosin ester also are giving promising results. This blend decreases after-tack, or softening, which heretofore has been a disadvantage of rosin-ester varnishes when made with either soybean or linseed oil. Thirty enamels made from 25 to 100 per cent. soybean oil have been prepared and tested in cooperation with the Chicago Paint and Varnish Production Club. These enamels together with two high grade commercial white enamels, have been exposed outdoors at Urbana and also subjected to an accelerated test by exposure to ultraviolet light indoors. After about 1,400 hours of intermittent exposure to ultraviolet light, 17 of the enamels show excellent durability and 7 show good durability. Both commercial enamels failed prior to 545 hours of exposure. The same trend has been observed in the outdoor exposure.

R. H. O.

Weather Bureau Stresses Importance of Research.—"First things First"—to enable the Federal weather service to keep abreast of farm, business and professional needs—is the aim of the U. S. Weather Bureau, says F. W. Reichelderfer, chief, in his annual report. Some needed changes have been made. Research continues to be the base on which better service is built. Aeronautics and radio have opened new possibilities to the weather man, but at the same time have made new responsibilities. Adapting the weather service to demands of a modern world and to developments in meteorology and kindred fields, means continuous advancement. Agricultural planning; forest, soil and water conservation programs, flood control—and even minor variations in climate which have changed the occupations and lowered the incomes of thousands of citizens—are among problems demanding aggressive attention. Because there are few human activities that can boast complete indifference to weather, present or future, Doctor Reichelderfer points out, it is increasingly necessary to know more and more about climatic changes and trends. The Weather Bureau is extending its network of climatological stations as rapidly as possible to meet these modern demands. To keep Weather Bureau personnel abreast of the latest in weather science, the Bureau in the past year has devoted much time to research and in-service training. These "refresher" studies not only keep weather men up-to-date, but help to lessen a shortage in trained personnel. The growing requirements of agriculture, aviation, and commerce exceed the capacity of present staffs in city offices and at airport stations. The Bureau also is aiding and encouraging weather science education and research in universities throughout the country.

R. H. O.

Experimental Foundry.—The Research Foundation of Armour Institute of Technology recently announced that the laying of the foundation for their experimental foundry is completed, and that construction of the new building is well under way. The construction of the foundry will mark the realization of a further step in a planned program for the developing of complete facilities for fundamental and applied research in the fields of iron and steel production, it was revealed by Harold Vagtborg, director of the Research Foundation. It will have complete research and testing facilities in the field of iron and steel production and will provide a large scale pilot plant which should prove invaluable to the iron and steel and allied industries. The foundry is to be used primarily in connection with the activities made possible by the Wetherill

Research Fund, recently established by Colonel S. P. Wetherill of Philadelphia. The Fund was specifically established for the purpose of advancing the method of counter-gravity die-casting of iron and other high melting metals. Die-casting of metals is a comparatively recent discovery and its development will be of tremendous significance to all industries. The method of counter-gravity die-casting replaces the old gravity flow sand mold with a metal mold located over the crucible of molten metal. The molten metal is forced through a refractory tube into the die, or mold, under air pressure. The resulting casting is far superior to the present sand mold casting being stronger, finer grained, and possessing a smooth surface not obtainable with the sand mold method of casting. The tensile strength of a gray iron casting obtained by the new method is about 40,000 pounds per square inch as compared with 25,000 pounds per square inch obtained by the present method. The greater smoothness of surface of the counter-gravity die-casting requires much less machining, permits casting to finer limits, and makes possible direct casting about bearing surfaces, and a variety of short-cuts never before attainable.

R. H. O.

Need Beeswax Purified For Cosmetics, Candles.—Beeswax, when pure, is fine material for high-quality candles, but impurities are likely to clog the candlewick and cause uneven burning and sputtering flame. Bees manufacture wax for combs. Pure wax will burn with practically no ash or smoke, but wax gathered from the hive usually contains pollen and the substance known as propolis or bee glue, which the insects gather from plants, a gummy resinous material that does not melt or burn at the same temperatures as pure wax. If particles of propolis are drawn into the wick, they prevent the even flow of the melted wax and may make a sooty smoke. To purify wax for candlemaking and for use in cosmetics, George H. Vansell, Federal entomologist, and C. S. Bisson, of the California Agricultural Experiment Station, have found that solar heating is likely to be more satisfactory than heating with boiling water. Sun heat helps to bleach the wax. Impurities may be further removed by boiling the wax in dilute acids which destroy the pollen and propolis without affecting the wax. These scientists have found that the darkening of the color which has been attributed to heating is really the result of chemical action that results when hot wax is in contact with iron. Wax can be kept hot for hours in containers of glass, stainless steel, aluminum, or nickel without darkening. For thread waxing, in grafting wax, and for waterproofing, the presence of propolis and pollen is no

disadvantage, but in making cosmetics and in pharmacy the propolis, in particular, is objectionable as it makes the wax much more acid, and mixtures which will be desirable in the pure wax may develop very differently because of the acid of the propolis.

R. H. O.

9,500 Foot Peak Discovered in Pacific.—A huge submarine mountain, or possibly a mountain range, rising 9,500 feet from the ocean floor, has been discovered by the Coast and Geodetic Survey, Department of Commerce, in the Gulf of Alaska 200 miles south of Kodiak Island, it was announced recently by Assistant Secretary of Commerce J. Monroe Johnson. Preliminary soundings taken by the survey ship *Surveyor*, in command of Lieutenant Commander Ray L. Schoppe, indicate that the base of the mountain measures more than 14 miles in width, and that its top reaches to within 4,700 feet of the surface of the water. "Similar underwater formations have been discovered in nearby Alaskan waters in recent years by the Coast and Geodetic Survey," Admiral Leo O. Colbert, Director, Coast and Geodetic Survey said, "but none as impressive as this one in its steep rise from the ocean bottom. Until further investigation is made it will be useless to speculate on the extent of these mountains, but the possibility exists that the area is an undersea replica of the giant peaks that form the Aleutian Islands." Since these submarine mountain ranges lie near the great circle shipping route between the Straits of Juan de Fuca and the Orient, when more fully surveyed, their distinctive formations will serve as underwater landmarks for transpacific vessels equipped with fathometers, equally as valuable as landmarks ashore. The fathometer is the modern device which flashes continuous soundings by the sound-echo principle while the vessel cruises at full speed. Further investigation of this area is planned for the spring when the Coast and Geodetic Survey fleet crosses the Gulf of Alaska enroute to its season's work along the Alaskan Peninsula and Aleutian Islands.

R. H. O.

Railway Progress.—That the overnight range of United States passenger transport has been increased from 500 miles to 1,000 miles in the post-war period, that freight-service-per-hour has increased 66 per cent., and that United States railroads have invested ten billion dollars in plant betterment during these years was revealed by F. G. Gurley, vice-president of the Santa Fe Railroads, in addressing the University of Michigan-Life Conference on New Technologies in Transportation recently. "Railroads today utilize the products of the inventor, the metallurgist, the scientist, the

engineer, and the builder," Mr. Gurley said. Among important experiments now being carried on by the railways, Mr. Gurley reported, are new braking devices for high speed passenger trains; improved freight car trucks, which it is hoped will ultimately make possible freight speeds as high as 85 miles per hour; the elimination of needless weight in freight cars; the turbo-electric locomotive; a new 5,400 horse power diesel locomotive for freight service; the Besler type locomotive that utilizes cylinders delivering power to each driver independently of each other; and lighter reciprocating parts of steam engines in an effort to reduce the undesirable effect of high dynamic augment (hammer blow) on railway track. One experiment of particular interest is a new type passenger car, known as the Hill car, embodying principles of construction radically different from those employed in conventional design, Mr. Gurley stated. The free floating body of this car is supported on its four corners by tall coil springs, which act as shock absorbers, eliminating practically all vibration, while the gondola-like body is unanchored at its base, so that the bottom of the car may move outward on curves, and the top inward, permitting the negotiation of curves at a higher speed than is possible with existing equipment, without discomfort to passengers. Three units of the car known as the "Hill car," are now under construction on the Pacific coast.

R. H. O.

American Journal of Physics is the new title of the bi-monthly publication known since its inception in 1933 as *The American Physics Teacher*, according to an action taken recently by the American Association of Physics Teachers concerning its official journal. Remaining under the editorship of Professor Duane Roller, of Hunter College, and under the publication management of the American Institute of Physics, the journal will continue to stress the educational, historical, socio-economic and philosophic aspects of physics, and the instruction of students who take physics as part of a liberal education as well as those who specialize in the science.